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CUTTER RESOURCE EFFECTIVENESS EVALUATION MODEL

VOLUME II - THE EVALUATION OF CRAFT PERFORMANCE IN COAST GUARD PROGRAMS

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June 1977

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DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
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Washington, D.C. 20590

NOTICE

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16. Abstract
This report documents the evaluation procedure utilized in the Cutter Resource Effectiveness Evaluation Model which quantifies craft performance in Coast Guard missions. Beginning with an introductory overview, this volume presents the craft available for evaluation and the details of the craft characteristic section of the CRAFT/TASK EVALUATION element of the CREE Computer Program. The report then describes the methodology utilized in task (the lowest level of discrete activity) performance evaluation and continues with the procedure of evaluating craft performance of sorties (sequenced tasks) and scenarios (sets of sorties). Finally this documentation describes how long-term operational evaluation of craft mission performance can be determined.

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METRIC CONVERSION FACTORS

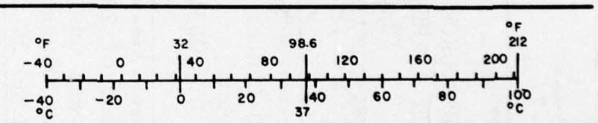
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This volume is one of a series which collectively documents the Cutter Resource Effectiveness Evaluation Project. The complete documentation includes the following:

- Executive Summary
- Volume I: Analysis and Synthesis of Coast Guard Programs
- Volume II: The Evaluation of Craft Performance in Coast Guard Programs
- Volume III: Utilization of the Cutter Resource Effectiveness Evaluation Model
- Users/Programmers Guide to the Cutter Resource Effectiveness Evaluation Computer Program

The study was requested in August 1974 by the Office of Operations and until August 1975 was directed by CAPT C. L. BLAHA, Chief, Plans and Programs Staff. Subsequent efforts have been directed by CAPT P. M. JACOBSEN, Chief, Plans and Programs Staff. The initial Project Monitor in G-OP staff was Mr. P. J. D'ZMURA. Since October 1975, LCDR B. C. MILLER of the G-OP staff has been Project Monitor. The Project Office in G-DOE-2 has been CDR A. TURNER.

This study was conducted by the Coast Guard Research and Development Center, Groton, Connecticut, with technical assistance from the Department of Transportation's research and development activity, Transportation Systems Center, Cambridge, Massachusetts. The full-time study team members were:

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1.0 INTRODUCTION

1.1 Technical Overview

To determine the potential for utilization of HPWC (High Performance Watercraft) and conventional craft in Coast Guard missions, an analytical model addressing both the job to perform and the capability of various resources has been developed. This model, called the Cutter Resource Effectiveness Evaluation (CREE) Model," is made up of three major elements as shown in Figure 1-1 and listed as follows:

a. Concepts of Operations
b. Craft/Task Evaluations
c. Scenario Calculations

Broadly speaking, the Concepts of Operations element is concerned with the job to be performed and the method of craft deployment. This is where the operational requirements are specified, various craft and suitable methods of deployment are chosen, and task-oriented scenarios are constructed.

The Craft/Task Evaluation element of the CREE Model consists of three sections that eventually provide a numerical evaluation of craft performance of a task. The first section, called Craft Characteristics, takes the craft concept specified in the Concept of Operations and determines typical detailed characteristics of that craft. The second section, called Parameter, uses these craft characteristics coupled with various operational requirements from the Concept of Operations, and calculates dimensionless numerical values (parameters) indicative of the craft's performance in a variety of areas, such as maneuverability at various operational speeds, towing ability, and seakindliness, to cite a few. These parameters form the input for the third section, the Task Probability of Success, which calculated the success of craft performance of a task. The outputs of the Craft/Task Evaluations element are numerical values indicative of how a given craft performs the given tasks with the specified operational requirements.

Finally, the Scenario Calculations element addresses the effectiveness of the craft performing in a larger arena - that of complete sorties or missions, in either single or multi-program scenarios. Since scenarios are made up of tasks, like search, tow, board or transit, and since craft performance of tasks is quantified in the Craft/Task Evaluations element, the Scenario Calculations element utilizes this Craft/Task Effectiveness output. These calculations are accomplished in the Program Probability of Success element of the CREE computer program, which has as its output, values for craft mission success for the specified Operational Requirements.

1.2 Organization and Content

This volume of the Cutter Resource Effectiveness Evaluation Report contains the technical rationale behind the development of a procedure which evaluates craft performance in Coast Guard Programs. That is, referring to the CREE Model organization in Figure 1-1, this volume addresses both Craft/Task

OVERVIEW OF CUTTER RESOURCE EFFECTIVENESS EVALUATION MODEL

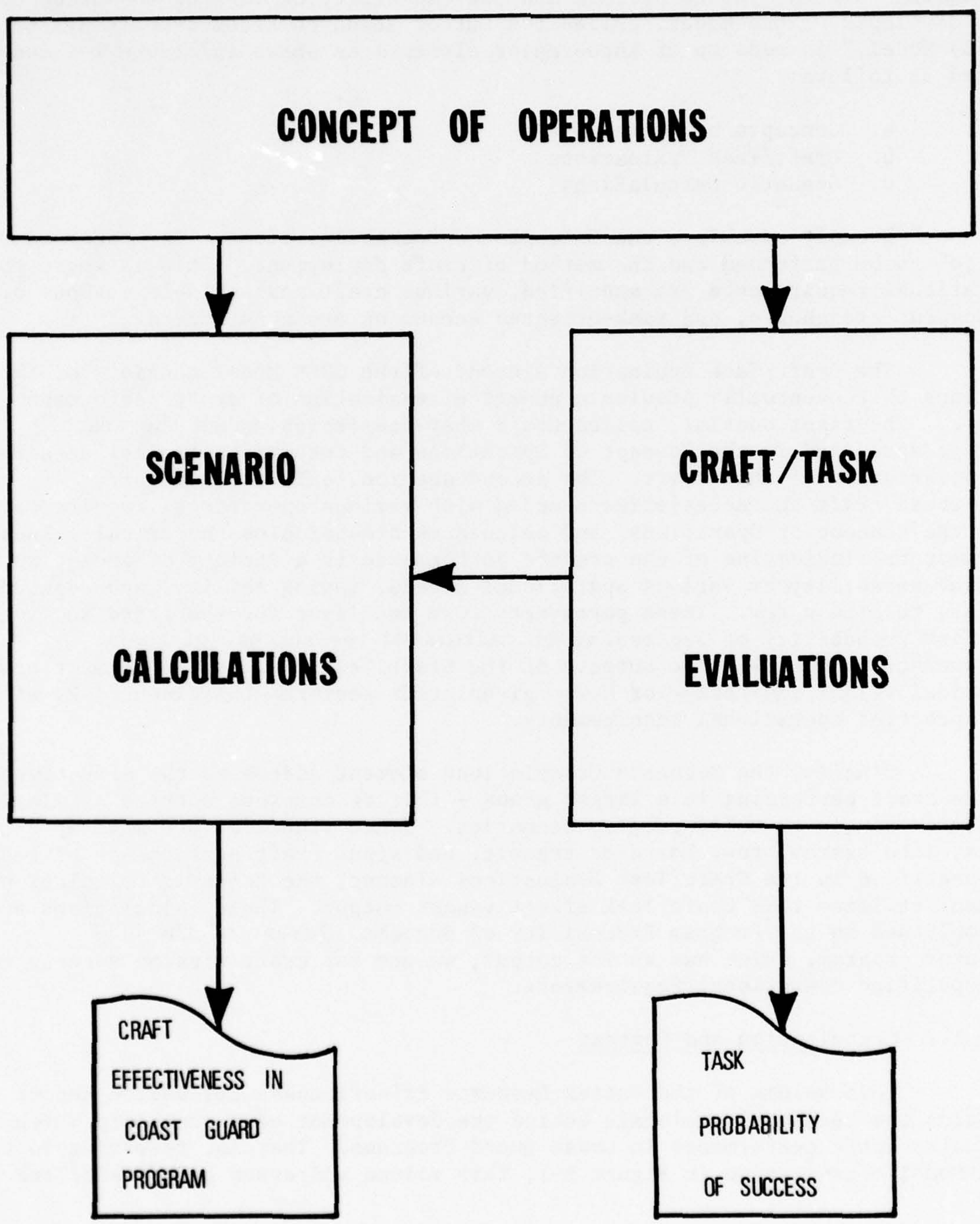


FIGURE 1-1

Evaluations and Scenario Calculations. Volume I of this report addresses Concepts of Operations, or the specification of the problem by the user of the model; Volume III contains some sample problems that have been addressed with the CREE Model.

This volume first presents the craft selection and definition of characteristics, and then describes and develops the evaluation procedures for these craft performing tasks, sorties and scenarios. Finally, a procedure is presented whereby the results of the CREE Model can be physically related to the goals of Coast Guard Programs.

2.0 RESOURCE DEFINITION AND DESCRIPTION

To enable accurate evaluation of HPWC and conventional craft performing in various missions, the operational and technical characteristics of the vessels considered must be known. This could be achieved by considering several specific designs of all possible HPWC types; for example, a 50-knot, 80-foot Submerged Foil Hydrofoil, a 40-knot, 130-foot Surface Piercing Foil Hydrofoil, a 60-knot, 100-foot Air Cushion Vehicle, a 40-knot, 90-foot Planing Craft. This is at best a "shotgun" approach, however, assuming the preferred specific designs are known in advance.

To provide flexibility, a craft characteristics program was devised as part of the CREE Model, which enables the user to specify certain critical characteristics of any one of the various types of HPWC or conventional craft and thereby fix his own design. Utilizing numerous computer-filed design relationships, the output of the Craft Characteristics program provides the significant technical and operational characteristics for the craft type specified by the user. These craft characteristics then form the starting point for subsequent calculations in the evaluation procedure.

For existing Coast Guard craft, the Craft Characteristics section need not compute the operational and technical features, as these are known quantities. In this case, a list of these known data is produced from stored tables. No design information can be specified by the user for such craft as these craft actually exist.

In summary, the Craft Characteristics section of the computer program provides a list of distinctive operational and technical features of user-chosen HPWC and conventional craft based upon several user-inputted characteristics.

2.1 Craft Selection

The user selects the craft desired for evaluation by specifying the following four inputs: (1) craft type, (2) size, (3) speed, and (4) fuel fraction of total useful payload. Only the TYPE Code need be specified for the CG craft (Types 101 through 112).

a. The Craft TYPE. Any of the following craft types can be selected.

TYPE CODE	CRAFT
10	Hydrofoil, Submerged Foil
11	Hydrofoil, Surface Piercing Foil
20	ACV (Air Cushion Vehicle) - Low cushion pressure
21	ACV - High cushion pressure
30	SES (Surface Effect Ship)
40	Planing Craft
50	Catamaran
60	SWATH (Small Waterplane Twin Hull)
70	Hybrid Vessel
80	Conventional Craft

TYPE CODE	CRAFT
101	MRB 26'
102	PWB 32'
103	UTB 41'
104	MLB 44'
105	MLB 52'
106	ANB 55'
107	ANB 63'
108	WPB 82'
109	WPB 95'
110	WMEC 210'
111	WMEC 270'
112	WHEC 378'

b. Craft Size. Either the length of the craft (feet) or displacement (tons) must be specified for the HPWC or Conventional TYPES. The limits on these length or displacement values are as follows:

TYPE AND CRAFT		ACCEPTABLE INPUT VARIATION OF SIZE	
		LENGTH (feet) -	DISPLACEMENT (tons)
10	HYDROFOIL, Submerged Foil	75-150	65-250
11	HYDROFOIL, Surface Piercing	70-150	25-200
20	ACV, Low Cushion Pressure	65-135	15-200
21	ACV, High Cushion Pressure	50-100	15-150
30	SES	100-150	90-250
40	PLANING	85-150	40-275
50	CATAMARAN	40-135	10-140
60	SWATH	100-300	500-3500
70	HYBRID	40-135	10-140
80	CONVENTIONAL	50-400	30-3500

c. Craft Speed. The maximum design speed of HPWC or Conventional craft from the below-listed set of design speed ranges must be specified.

CRAFT TYPE		MAX VARIATION OF SPEED INPUT (KNOTS)
10	HYDROFOIL, Submerged Foil	40-50
11	HYDROFOIL, Surface Piercing	30-40
20	ACV, Low Cushion Pressure	50-70
21	ACV, High Cushion Pressure	40-60
30	SES, High Length to Beam Ratio	30-40
40	PLANING	35-45
50	CATAMARAN	30-40
60	SWATH	15-25
70	HYBRID	30-40
80	CONVENTIONAL	15-30

d. Fuel Fraction. The percentage of total useful payload to be carried as fuel must be specified as a decimal fraction, F_f. F_f has upper and lower limits of 0.80 and 0.20 respectively.

2.2 Craft Characteristics

As discussed earlier, a large number of HPWC design relationships have been developed and stored as computer-filed information in the craft characteristics section of the computer program. This allows the user to obtain a complete listing of distinctive craft characteristics for the craft specified by his input. Appendix A contains CALCOMP plots (computer-drawn graphs) of this stored information. The methodology utilized to calculate these characteristics is depicted by the "Schematic Diagram for Craft/Task Evaluation" shown in Appendix B. This diagram portrays each step necessary to calculate the characteristics and indicates at what point in the arithmetic procedures the file information is utilized.

The computer-filed design information is only as detailed and precise as necessary to distinguish between the different capabilities of the various types of HPWC and conventional vessels; the relationships used are linear, piecewise linear, or logarithmic approximations. The relationships represent present or near-term technology and are general in nature. The program will provide distinctive technical and operational features of various HPWC only to that degree of precision needed to accurately evaluate the effectiveness of various craft and types in mission scenarios. The program will not provide an optimal design from a ship designer's viewpoint, but is only a tool to assist in the determination of the suitability of various craft for Coast Guard missions.

Table 2-1 illustrates the craft characteristics output format and content.

TABLE 2-1

CRAFT CHARACTERISTICS OUTPUT PAGE FORMAT

C R A F T   C H A R A C T E R I S T I C S

CRAFT TYPE		NAME
DISPLACEMENT	#	TONS
LENGTH	#	FEET
DESIGN SPEED	#	KNOTS
FUEL FRACTION	#	RATIO

LENGTH	#	FEET
BEAM	#	FEET
DRAFT	#	FEET
LENGTH/BEAM RATIO	#	
DRAFT/LENGTH RATIO	#	
DISPLACEMENT	#	TONS
SURVIVABILITY	#	SEA STATE
TOWS VESSELS UP TO	#	TONS
USEABLE DECK AREA	#	SQUARE FEET
CARGO CAPACITY	#	TONS
FUEL CAPACITY	#	TONS
USEFUL PAYLOAD	#	TONS
INSTALLED POWER	#	HORSEPOWER
POWER TO WEIGHT	#	HP/TON
TRANSPORT EFFICIENCY	#	HP/TON-KNOT
RANGE AT CRUISE SPEED	#	NAUTICAL MILES
ENDURANCE AT CRUISE SPEED	#	HOURS

	FLANK SPEED	CRUISE SPEED	REDUCED SPEED	ON SCENE	
ENGINE TYPE	(#)	(#)	(#)	(#)	
CALM WATER SPEED	#	#	#	#	KNOTS
SFC (WEIGHT)	#	#	#	#	LBS/HP-HR
SFC (VOLUME)	#	#	#	#	GAL/HP-HR
HP UTILIZED	#	#	#	#	HP
FUEL CONSUMPTION	#	#	#	#	GAL/HR
FUEL CONSUMPTION	#	#	#	#	GAL/NAUT MI
ENDURANCE (FUEL)	#	#	#	#	HOURS
RANGE	#	#	#	#	NAUTICAL MI
TURNING RADIUS	#	#	#	#	YARDS
CRAFT MOTION	#	#	#	#	G
AVG FUEL RATE	#	#	#	#	GAL/HR
AVG SPEED	#	#	#	#	KNOTS
TOW SPEED	#	#	#	#	KNOTS

3.0 TASK EVALUATION

A task is defined as the lowest level of discrete activity that can be identified in vessel or personnel mission performance. One of the basic premises of the model is that the most elementary level of craft comparison is made at the task level.

When evaluating craft performance of a task, two distinct aspects of this performance must be addressed, i.e., how much can be completed and how well is it done. In this model, the quantity of task accomplishment is represented by the probability of successfully completing any given task, and quality of performance is described by quality indicators such as time to complete the task, and the fuel used in completing the task.

This section, TASK EVALUATION, addresses both aspects of this evaluation and presents the rationale used to quantify these two components.

To evaluate craft performance of the many tasks included in this model, it first should be noted that this model only considers task accomplishment and performance as it is dependent upon craft selection, and that several different tasks, from the sole consideration of craft selection, may be equivalent. For example, Fighting Fire on Another Vessel is obviously vastly different from Seizing, but from the CG craft point of view, both require the CG craft to wait while on the other vessel a fire is put out or a seize is performed. In both cases, therefore, the action of the CG craft is the same. It is organizationally most convenient to assemble all such similar tasks into sets so that each task within any given set can be evaluated in the computer in the same manner. This effectively reduces the total number of tasks that must be considered yet does not reduce the accuracy of the model. The sets are called Master Tasks, and each individual task will have a corresponding Master Task. Table 3-1 is a Master and Individual Task listing.

3.1 Quantity of Task Accomplishment - Probability of Success

The probability of successfully completing a task is indicative of the quantity of achievement, and can be used to realistically represent how much of a given job or workload can be accomplished. Although there is a degree of uncertainty when expressing the quantity of accomplishment by a probability of success, several attractive features of this procedure make the probability of success a highly desirable measure.

Assuming more work performed is better, larger values of probability of success are better. Moreover, in a comparison of two probabilities of success, a value of 0.80 is twice as good as a value of 0.40. Since a probability of success can be easily understood and physically interpreted, numerical solutions expressed as probabilities of success are more palatable to the non-analyst reviewer or decision maker. Finally, since a probability of success represents yes/no situations, it can be experimentally measured, thereby providing an ideal validation procedure.

TABLE 3-1

MASTER-INDIVIDUAL TASK LIST

SPEED CATEGORY	MASTER TASKS	INDIVIDUAL TASKS
ON SCENE TASKS	ASSIST	-General Assistance
	BOARD	-Board -Retrieve Boarding Party
	MONITOR ACTIVITIES	-Monitor Activities -Monitor Oil Spill -Stake-out Special Interest Vessel
	RETRIEVE	-Retrieve Objects -Retrieve People
	WAIT	-Fight Fire on Another Vessel -Inspection -Loiter -On Board Assistance -On Scene Commander -Seize -Work Equipment from Small Boat
	WORK EQUIPMENT AT DRIFT	-Work Equipment at Drift
	WORK EQUIPMENT AT POSITION	-Fight Fire from CG Vessel -Load Equipment -Launch Small Boat -Retrieve Small Boat -Take Water Sample -Unload Equipment -Work Equipment at Fixed Position
REDUCED SPEED TASKS	SEARCH DISTRESSED UNIT	-Search for distressed unit
	SLOW ESCORT	-Slow Escort
	SEARCH PEOPLE	-Search for People
	SLOW PATROL	-Slow Patrol
	TOW	-Tow
CRUISE SPEED TASKS	ESCORT	-Escort
	IDENTIFY	-Identify Craft -Identify Fleet
	PATROL	-Patrol
	SEARCH TARGET	-Search for ship
	TRANSIT	-Search for Fleet -Transport People -Transit
	TRANSPORT	-Transport Equipment
FLANK SPEED TASKS	RESPOND	-Dash -Interdict

3.1.1 Definition of Probability of Success

In this model the probability of success is defined as the ratio of the number of times a task is successfully performed to the number of times it was attempted. The probability of a craft successfully completing a task is dependent upon the capabilities and limitations of the craft (craft characteristics), and upon the operational requirements, such as the sea state, visibility, distances and workload. These factors affecting the probability of success are each numerically described by parameters, which range in value between 0.0 and 1.0, and which express a degrading effect upon an initially assumed perfect task performance. The probability of success of a task is obtained by multiplying each of the parameters together.

$$\text{Probability of Success (Task)} = \prod_{i=1}^{N} PA_i$$

where N is the total number of parameters (PA) multiplied together

Since parameters reflect the degradation in the quantity of work that can be performed due to a particular factor, multiplication of the parameters is a legitimate method of combining all of the factors affecting task performance to obtain a task probability of success, assuming we have chosen factors that are independent.

3.1.2 Parameters

The parameters described below illustrate the aforementioned degradation of craft capability and operational requirements upon task completion or probability of success.

CARGO CAPACITY (CC) indicates whether or not cargo can be carried on board a given craft. Cargo required to be transported is specified by two numbers, its weight and "footprint" area. Similarly the craft capacity is characterized by the two analagous quantities, its cargo weight capacity and its deck area available for cargo stowage. If the craft's deck area and cargo capacity are both greater than or equal to the cargo weight and footprint, then the craft is able to carry the piece of cargo.

CC is calculated using the following Kronecker Delta product form:

$$CC = \delta_A * \delta_\Delta$$

where: $\delta_A = 1$ if deck area $\geq$ footprint of cargo, zero otherwise

$\delta_\Delta = 1$ if cargo capacity $\geq$ cargo/gear weight, zero otherwise

CC is then, a four argument function (craft area and capacity and cargo area and weight) which must satisfy the above rules. It has only two values (1 or 0) depending upon the gear being considered.

The footprint and weight of the cargo must be specified by the user whenever the scenario contains a Transport Equipment task. The craft deck area and cargo capacity are calculated in the Craft Characteristics section of the computer program for the specific craft under consideration. Note that a craft's cargo capacity (weight) is influenced by the user's choice of fuel fraction which is his specification of the percentage of total useful payload to be devoted to fuel. The craft deck area and cargo capacity are also a function of the type and size of craft specified by the user.

TOW PARAMETER (TW). Since all vessels are limited in the maximum size of the vessel they can tow, the TOW PARAMETER quantifies the towing capability of a craft with respect to a user-supplied distribution of vessels to be towed. In setting up the problem for investigation, the user specified this distribution of vessels to be towed by using either available SAR data or his own estimates. To arrive at the value for TW, this distribution is integrated from zero to the maximum size of vessel that can be towed by the craft under consideration.

$$TW \equiv \int_0^{\Delta max} P(\Delta)d\Delta$$

where:

$P(\Delta)$ is the probability distribution of vessels to be towed

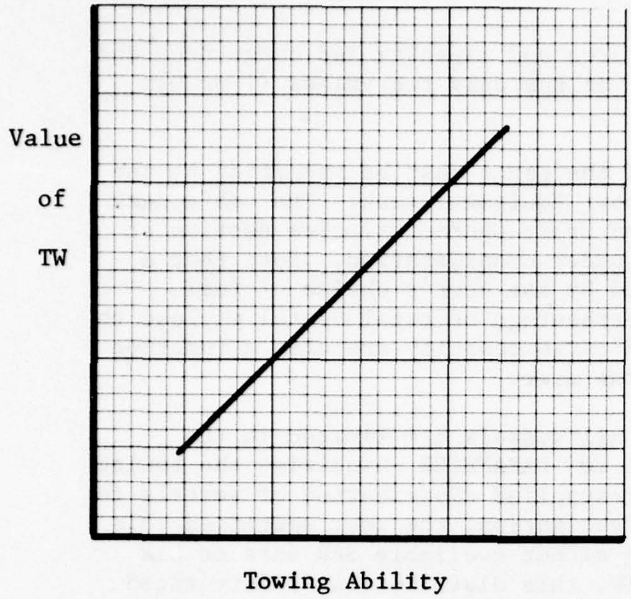
Δmax is the maximum size of tow by craft under consideration

This number, TW, is then, the fraction of all vessels required to be towed which can be towed by the considered craft. Since the towing distribution can be varied by the user, the value for TW changes with different distributions specified. It should be noted that all towing is performed at a user-inputted reduced speed, but speed does not affect the value of TW.

These points and others are highlighted in Figure 3-1, Tow Parameter Trend Diagrams, where TW is shown to increase as towing ability increases and decrease as the size of the towed vessels increases.

The following algorithm is used to determine the size of the average vessel towed: the cumulative probability of the towing distribution (CPT) at the craft's maximum towing capability (Δmax) is divided by two, and the curve re-entered with this value of $CPT_{\Delta max}$ as shown in Figure 3-2. This yields a "one-half" or average value of vessels towed (Δtow).

The towing speed associated with Δtow is determined using Figure 3-3 wherein $\Delta craft$ is the displacement of the craft being evaluated in the model.



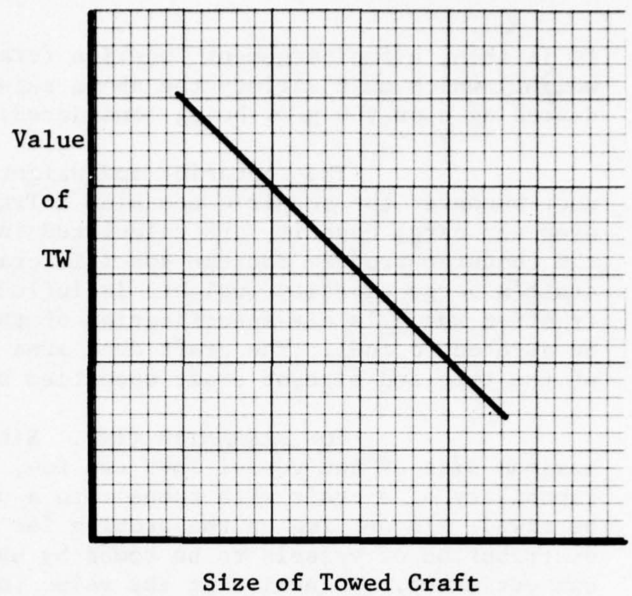


Figure 3-1 TOW PARAMETER TREND DIAGRAM

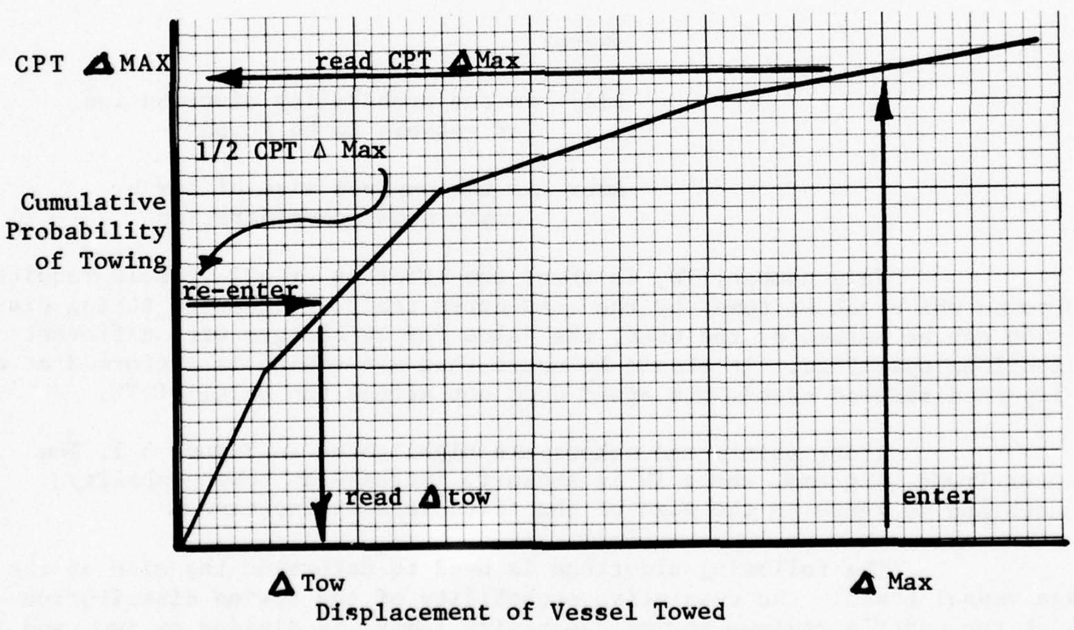


Figure 3-2 PROCEDURE TO DETERMINE SIZE OF AVERAGE VESSEL TOWED

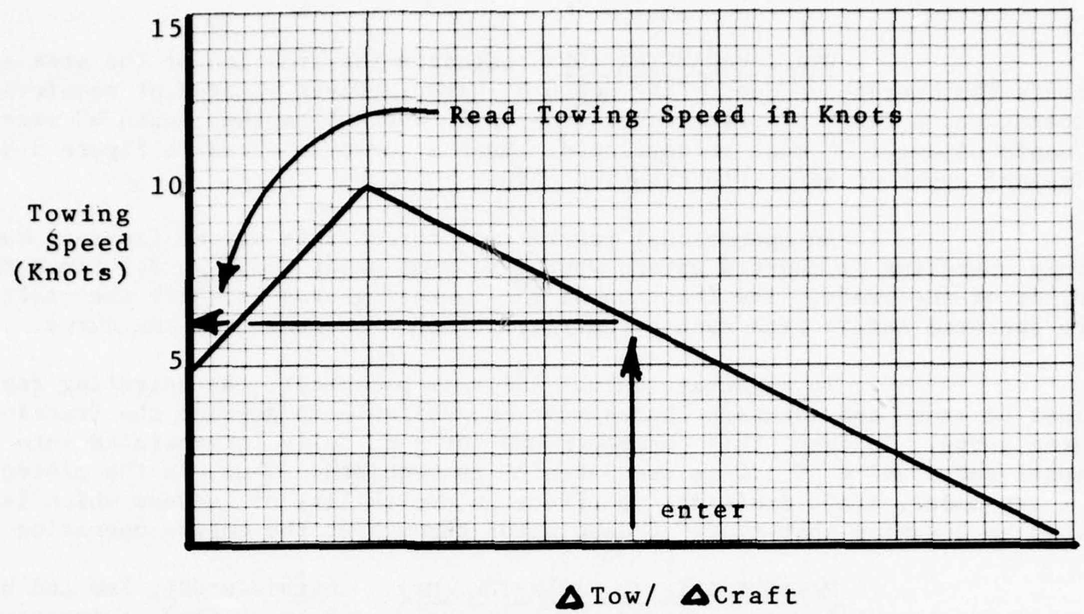


Figure 3-3 DETERMINATION OF TOWING SPEED

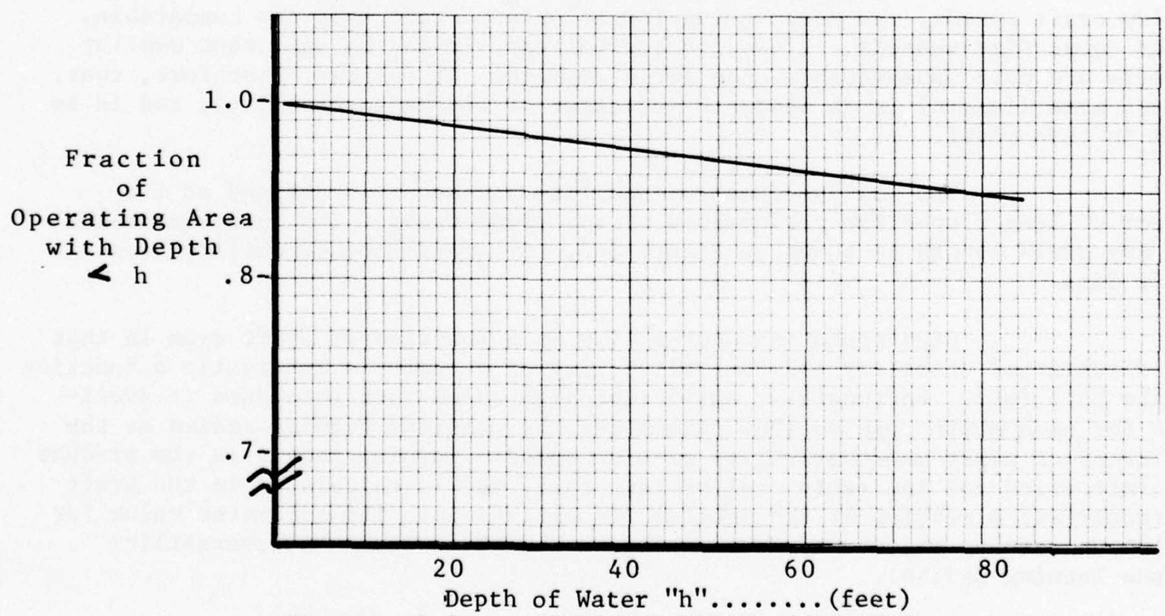


Figure 3-4 TYPICAL DEPTH OF WATER DISTRIBUTION CURVE

DRAFT PARAMETER (DF) indicates the fraction of the area a given craft can operate in due to the depth of water. Given an area of required operation, a curve of "fractional areas with depth less than depth h" versus "depth of water h" must be developed. Such a curve is shown in Figure 3-4, Typical Depth of Water Distribution Curve.

An operational restriction for a craft may be imposed, such as only operating in charted waters where the mean water depth is 2.5 times the draft of the craft. The fraction of the operating area in which the craft could be operated safely with such a restriction could be read from the curve.

To calculate values for this parameter, the operating region must be known and accurate charts must be available to develop the fractional area curve. To date, this parameter has not been fully incorporated into the model and a value of 1.0 is used when DF is required. Thus, in the present form of the model, craft draft has no effect on probability of success which is the same as assuming that there is deep water throughout the entire operating region.

MANEUVERABILITY PARAMETER (MN). In this study, low and high speed maneuverability are considered separately, and quantified as fractions of vessel size and turning radius respectively.

Low speed maneuverability is considered to be independent of craft type. This assumes that any desired maneuverability characteristics, such as helm response, turning radius, acceleration or stopping abilities, can be designed and built into any of the high performance or conventional craft. This is a realistic assumption as many maneuver-assisting devices are available for each craft type. Some of these devices include controllable pitch propellers, bow thrusters, rotating pylons, twin shafts, or sophisticated control systems. At low craft speeds, the maneuvering forces on any craft type are comparable, given equal size vessels. Viewed in another way, it can be said that smaller vessels are more maneuverable than large vessels. It follows, therefore, that, vessel size (length) is an adequate indicator of the maneuverability, and is so used in this model.

The low speed maneuverability parameter is defined as the effect of length upon the performance of low speed tasks. The parameter value for any given length is shown in Figure 3-5, Low Speed Maneuverability Versus Craft Size.

High speed maneuverability is a function of craft type in that the directional stability and controllability of a craft is inherently a function of the hull form. Fortunately, sufficient high speed turn rate data is available for each craft type so that this model can consider turning radius as the indicator of craft maneuverability at high speed. Turning radius is the product of craft speed and the reciprocal of turn rate, and is calculated in the Craft Characteristics section of the program for all speeds. The parameter value for any given turning radius is shown in Figure 3-6, High Speed Maneuverability Versus Turning Radius.

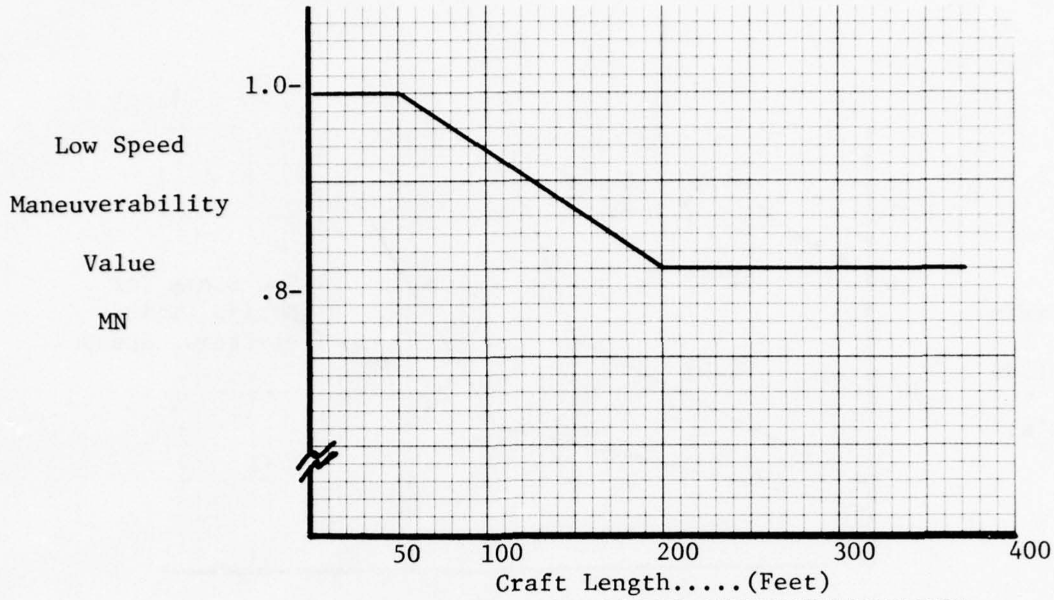


Figure 3-5 LOW SPEED MANEUVERABILITY VERSUS CRAFT SIZE

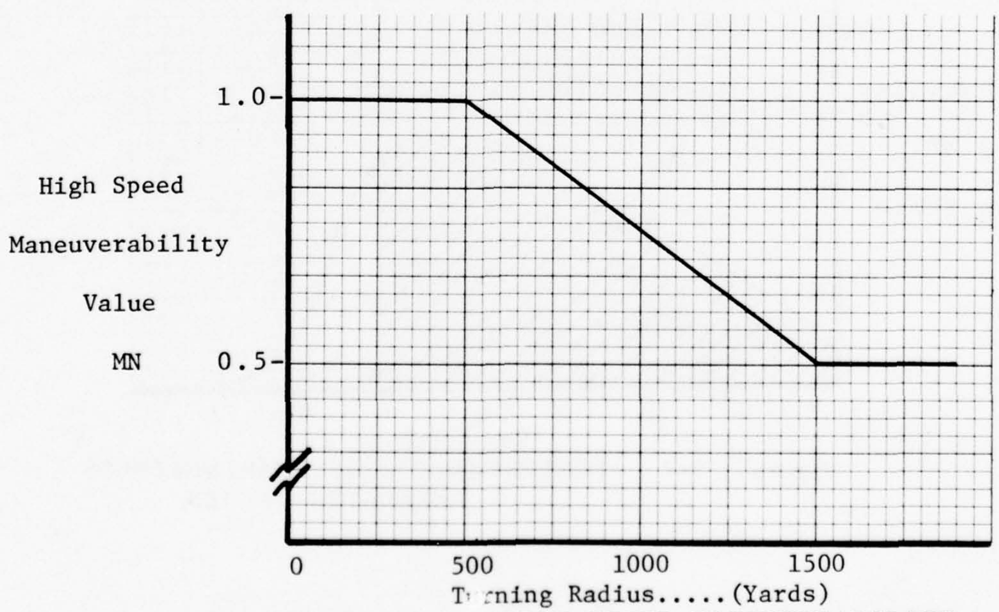


Figure 3-6 HIGH SPEED MANEUVERABILITY VERSUS TURNING RADIUS

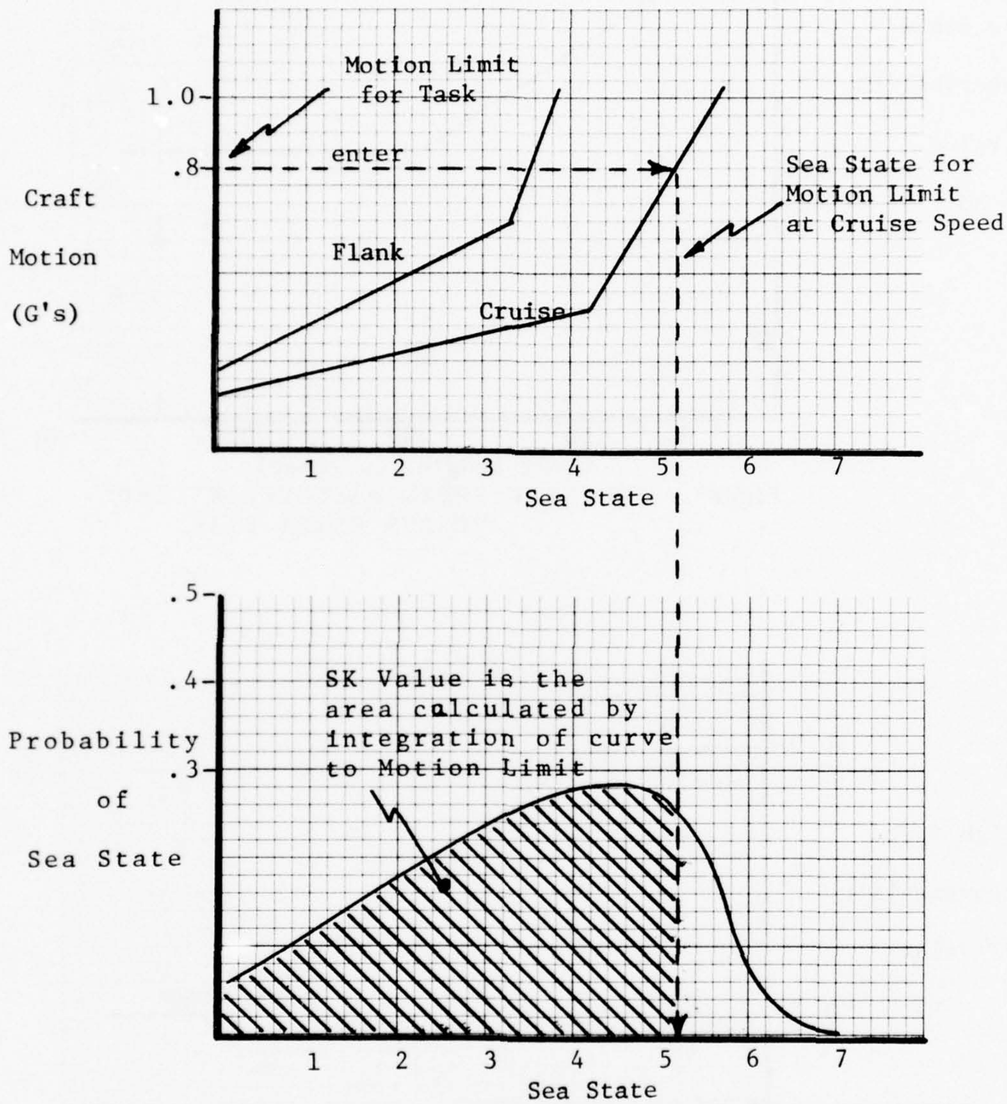


Figure 3-7 DETERMINATION OF SEAKINDLINESS PARAMETER VALUES

TABLE 3-2

MAXIMUM ACCEPTABLE LEVELS OF CRAFT MOTION

SPEED CATEGORY	MASTER TASK	MAXIMUM ACCEPTABLE CRAFT MOTION (G's)
ON SCENE TASKS	Assist	.7
	Board	.6
	Monitor Activities	.8
	Retrieve	.5
	Wait	.9
	Work Equipment at Drift	.5
	Work Equipment at Position	.5
REDUCED SPEED TASKS	Search Distressed Unit	1.0
	Search People and Objects	1.0
	Slow Escort	N/A
	Slow Patrol	N/A
	Tow	1.0
CRUISE SPEED TASKS	Escort	N/A
	Identify	1.0
	Patrol	N/A
	Search Target	1.0
	Transit	N/A
	Transport	N/A
FLANK	Respond	N/A

SEAKINDLINESS PARAMETER (SK). The Seakindliness Parameter indicates the fraction of task occurrences that can be performed successfully when the performance of the task is hindered or prevented by craft motion due to the sea state. The procedure for determining the value of the SK parameter is outlined below.

For a given task, the limit of maximum craft motion where the task can no longer be performed is identified. Using the craft motion versus sea state envelopes of the Craft Characteristics section of the program, the sea state at which this motion occurs is determined. This is a function of the craft type, size and task speed. The sea state distribution specified by the user when setting up the problem is then integrated from zero to this maximum acceptable motion value of sea state. The resulting number is the fraction of the total number of times which that task may be successfully performed.

Figure 3-7, Determination of Seakindliness Parameter Values, illustrates this procedure, and Table 3-2 shows the maximum acceptable levels of craft motion for all tasks.

The GO FRACTION PARAMETER (GO) indicates the probability that a craft can achieve speeds in a seaway greater than some established minimum speed. Any speed less than the minimum speed is "inordinately slow," hence not worth going and equivalent to a "NO GO." For Flank, Cruise, Reduced Speed and On Scene, these lower speed limits are chosen to be 15, 8, 5 and zero knots, respectively.* The sea state which limits the craft to the acceptable minimum speed is read from the speed-sea state envelope for each selected steaming speed. The sea state probability is then integrated from zero to this speed, SS(V).

$$GO \equiv \int_0^{SS(V)} P(SS)dSS$$

where: P(SS) is the probability of sea state

SS(V) is the sea state of the lower speed limit

GO is dependent upon the choice of the "inordinately slow speed," the sea state distribution, and the craft speed-sea state envelope. This parameter is computed for all selected steaming speeds.

The relationship of GO to these variables may be seen in Figure 3-8, GO Parameter Trend Diagrams.

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*These lower speed limits for the GO Parameter affect the probability of success for every task through the Limiting Sea State (LS) Parameter (see Table 3-2). Hence, the results of the CREE Model are very sensitive to these speed limit values.

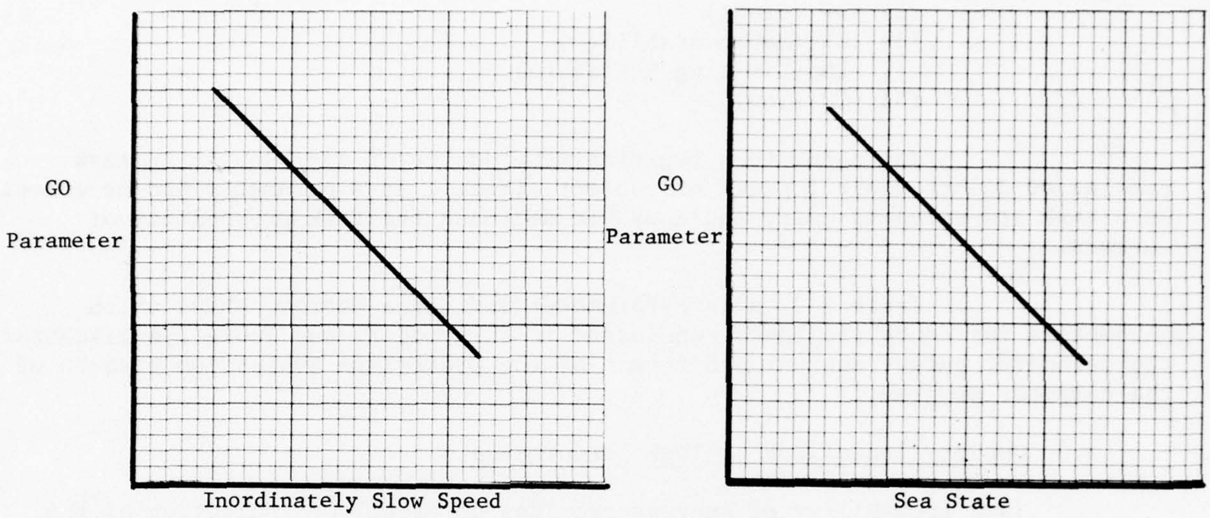

Figure 3-8 GO PARAMETER TREND DIAGRAMS

SURVIVABILITY PARAMETER (SU). The survivability parameter is a measure of the maximum sea state which a craft can endure and then continue on its mission. Sea states higher than the survivability sea state do not mean that the craft sinks, only that it is totally unable to operate in the specified environment. SU is calculated by integrating the sea state probability distribution between the limits of zero and the survivability sea state of the craft. The survivability sea state is a function of the type and size of craft and is calculated for the specific craft under consideration in the Craft Characteristics section of the program.

LIMITING SEA STATE PARAMETER (LS). The GO, SURVIVABILITY and SEAKINDLINESS parameters each express the fraction of expected seaways in which a craft can successfully perform a given task. Since the sea state is the limitation in each of these parameters, the effect of sea state upon task performance would be triple weighted in the task probability of success if all three parameters were considered. It is necessary therefore to define a Limiting Sea State parameter which is the minimum of any of the "sea state" parameters previously discussed. The use of the Limiting Sea State parameter therefore, allows the task probability of success calculations to consider only the single most significant degradation in task performance due to sea state.

3.1.3 Summary of Task Probability of Success

The task probability of success is the product of five parameters:

(1) CC (Cargo Capacity)
(2) DF (Draft)
(3) MN (Maneuverability)
(4) LS (Limiting Sea State)
(5) TW (Tow)

The parameters represent the degree of degradation in task completion due to their topical or subject effect. If a parameter has no effect on a task its value is unity and does not decrease the task probability of success.

Table 3-3, a Task-Parameter Influence Matrix, shows which parameters influence the tasks considered in this model, and Table 3-4 illustrates the parameter output content and format of the Craft/Task Evaluation element of the computer program.

3.2 Quality Indicators of Task Performance

Task probability of success provides an excellent indication of the quantity of work that can be performed, however it gives no information on the quality of performance, or how well a task is performed. In general, when evaluating craft performance, two significant indicators of quality are the time required to complete the task, and the amount of fuel consumed while performing the task. Other factors, like craft habitability during task performance, can be considered if desired, but because these "softer" indicators do not affect ability to perform a task, they tend to obfuscate the evaluation process by increasing the volume of information that must be digested.

It should be pointed out that this discussion focuses upon quality indicators while performing a task. The craft related features of range, endurance, complement, and so forth are a separate matter and should not be confused with the indicators describing how well a task is performed.

3.2.1 Time to Perform a Task

The time to perform any given task may be dependent upon a variety of items depending upon the particular task. Consequently, each task must be considered individually in the "time" calculation procedures. In general, however, the time to perform most tasks is a function of the operational requirements, or the user stated-inputs that initiate the problem, and the characteristics of the craft performing the task.

For example, the distances specified by the user in his scenario construction and the craft speed in the sea state determine the time required to transit from a home port to the patrol or on scene area. As a further level of sophistication in this transit time example, the visibility distribution specified by the user is taken into account when calculating the

TABLE 3-3

PARAMETER INFLUENCE MATRIX
(where X denoted influence)

MASTER TASKS \ PARAMETERS	CARGO CAPACITY CC	DRAFT DF	LIMITING SEA STATE LS	MANEUVER ABILITY MN	TOW TW
ON SCENE TASKS					
Assist/Board		X	X	X	
Monitor Activities		X	X	X	
Retrieve		X	X	X	
Wait			X		
Work Eqmt. (Drift)		X	X		
Work Eqmt.(Position)		X	X	X	
REDUCED SPEED TASKS					
Search Dist. Unit		X	X		
Search People/Obj		X	X		
Slow Escort			X		
Slow Patrol		X	X		
Tow			X	X	X
CRUISE SPEED TASKS					
Escort			X		
Identify			X	X	
Patrol			X		
Search Target		X	X		
Transit			X		
Transport Eqmt.	X		X		
FLANK SPEED TASKS					
Respond			X		

TABLE 3-4

CRAFT PARAMETERS OUTPUT PAGE FORMAT

```
          C R A F T   P A R A M E T E R S

          CRAFT TYPE           NAME
          DISPLACEMENT    #    TONS
          LENGTH          #    FEET
          DESIGN SPEED    #    KNOTS
          FUEL FRACTION   #    RATIO

               VISIBILITY DISTRIBUTION NO. #
               TOW DISTRIBUTION NO. #
               DEPTH DISTRIBUTION NO. #
               SEA STATE DISTRIBUTION NO. #
               (AVERAGE SEA STATE= # )


     TASK   CARGO DRAFT MANEUV  SEA    TOW
     CODE   CPCTY               STATE

             CC      DF     MN     LS     TW


ON SCENE:
     ASST    #       #      #      #      #     ASSIST
     BORD    #       #      #      #      #     BOARD
     MNAC    #       #      #      #      #     MONITOR ACTIVITIES
     RTRV    #       #      #      #      #     RETRIEVE
     WAIT    #       #      #      #      #     WAIT
     WEQD    #       #      #      #      #     WORK EQUIPMENT & DRIFT
     WEQP    #       #      #      #      #     WORK EQUIPMENT & POSITION

REDUCED SPEED:
     SDIU    #       #      #      #      #     SEARCH FOR DISTRESSED UNIT
     SESC    #       #      #      #      #     SLOW ESCORT
     SPAT    #       #      #      #      #     SLOW PATROL
     SPFO    #       #      #      #      #     SEARCH FOR PEOPLE
     TOWS    #       #      #      #      #     TOWS

CRUISE SPEED:
     ESCT    #       #      #      #      #     ESCORT
     IDNT    #       #      #      #      #     IDENTIFY
     PATL    #       #      #      #      #     PATROL
     STGT    #       #      #      #      #     SEARCH FOR TARGET
     TRPT   ****     #      #      #      #     TRANSPORT
     TRST    #       #      #      #      #     TRANSIT

FLANK SPEED:
     RSPD    #       #      #      #      #     RESPOND


**** DEPENDENT UPON SCENARIO (E.G., FOOTPRINT AND WEIGHT OF CARGO)
```

time required for this transit because, with reduced visibility, the craft will not be able to steam at the maximum allowable by the craft speed-sea state relationship, but at some slower speed for safety purposes.

Appendix C presents the equations and algorithms used to calculate the times to complete all of the Master Tasks in this model with the exception of certain search type tasks which are presented in Appendix D, The Search Task Equation Development.

3.2.2 Fuel Consumed During Task Performance

Given the "time to complete" any task from the foregoing, and the craft's fuel consumption rate, the fuel consumed is the product of the task time and the craft's fuel consumption rate. It is important to note that the craft's fuel consumption rate is a function of the speed of the craft while it is performing the particular task, and that the Craft Characteristics section of the program provides these fuel consumption rates for the speeds used in this model.

3.3 Overall Task Evaluation

The primary evaluation of craft performance of a task is the probability of success as this number indicates "how much" a given craft can be expected to accomplish. Table 3-5 illustrates the computer-output format for Master Task Probabilities of Success.

Inasmuch as the probability of success only considers completion or non-completion of a task, the two quality indicators of task time and fuel consumed are also necessary ingredients of task evaluation. These two quality indicators more fully describe the successfully completed tasks and thus provide the user of the model with a clearer insight into the overall expected task performance.

The probability of success and the quality indicators used to evaluate craft performance of a task, are highly dependent upon two items, first, the user-inputed operational requirements, such as expected sea state, and second, the craft characteristics themselves. Any evaluation should precede with an understanding of how different operational requirements, or different characteristics would affect the model results.

In short, before specific recommendations based upon these outputs are made, the user should expect, fully understand and be able to explain, the numerical values calculated and outputted by this model.

TABLE 3-5

TASK PROBABILITY OF SUCCESS OUTPUT PAGE FORMAT

T A S K   P R O B A B I L I T I E S   O F   S U C C E S S

CRAFT TYPE NAME
DISPLACEMENT # TONS
LENGTH # FEET
DESIGN SPEED # KNOTS
FUEL FRACTION # RATIO

VISIBILITY DISTRIBUTION NO. #
TOW DISTRIBUTION NO. #
DEPTH DISTRIBUTION NO. #
SEA STATE DISTRIBUTION NO. #
(AVERAGE SEA STATE= #)

TASK CODE	TASK PROB. OF SUCCESS		TASK
ON SCENE:			
ASST	#		ASSIST
BORD	#		BOARD
MNAC	#		MONITOR ACTIVITIES
RTRV	#		RETRIEVE
WAIT	#		WAIT
WEOD	#		WORK EQUIPMENT @ DRIFT
WEOP	#		WORK EQUIPMENT @ POSITION
REDUCED SPEED:			
SDIU	#	*	SEARCH FOR DISTRESSED UNIT
SESC	#		SLOW ESCORT
SPAT	#		SLOW PATROL
SPEO	#	*	SEARCH FOR PEOPLE
TOWS	#		TOWS
CRUISE SPEED:			
ESCT	#		ESCORT
IDNT	#		IDENTIFY
PATL	#		PATROL
STGT	#	*	SEARCH FOR TARGET
TRPT	*****		TRANSPORT
TRST	#		TRANSIT
FLANK SPEED:			
RSPD	#		RESPOND

* THIS IS THE P.O.S. OF THE ABILITY TO SEARCH. CRAFT"S SUCCESS IN FINDING THE OBJECT OF THE SEARCH IS DEPENDENT UPON SCENARIO (E.G., SEARCH AREA)

***** DEPENDENT UPON SCENARIO (E.G., FOOTPRINT AND WEIGHT OF CARGO)

4.0 SORTIES

This model, which uses flow chart scenarios to represent program or mission activity, defines a sortie as any complete path of the flow chart. In a typical flow chart scenario, there are a large number of possible paths, and hence a large number of sorties. Each sortie then represents a different sequence of activity in one scenario, and is a specific sequence of tasks.

The sortie is the next higher level of activity above a task, and can physically be described as any typical SAR case, harbor oil spill patrol, or daily fishing fleet identification and inspection operation. Generally speaking a sortie implies a daily sequence of activities, starting and terminating from the same location, however this does not necessarily have to be the case. Any complete sequence of tasks from a scenario is a sortie, even if it requires more than twenty-four hours to complete.

4.1 Sortie Evaluation Procedure

As a logical extension of task evaluation, it might be expected that the sortie evaluation procedure would consist of multiplying the probabilities of success of all the sequenced tasks together to obtain a level of sortie performance. Unfortunately this method will not provide a realistic value for a sortie performance primarily because of the dependence or coupling between similar parameters in different tasks.

For example, sea state usually affects more than one task in a sortie, and the <u>same</u> sea state affects successful completion of <u>different</u> tasks in the sequence. Thus multiplying the task probabilities of success together to obtain a value for sortie performance would compound the effect of sea state in sortie evaluation.

Similar coupling or dependence also exists between other parameters. In addition, careful examination of typical sorties illustrates that the sortie performance should be independent of the number of sequenced tasks; otherwise, more meticulous scenario construction, i.e., more detailed representation of the operation by the use of more tasks, would decrease the sortie performance.

With these initial thoughts in mind, and recalling that task probabilities of success are products of parameters which describe craft characteristics, workload and environmental conditions, a method of calculating a value for sortie performance is to synthesize one using the product of parameters.

Since each task is described by a value for each parameter, and since a sortie is a sequence of tasks, a sortie can be completely described by a matrix of parameter values. To quantify the sortie performance from these matrix entries, the minimum value of each major parameter is selected. The minimum value is chosen because the minimum value of the parameter corresponds to the maximum degradation effect of the parameter on any task in the sortie. It is assumed that the effect of the parameter on the other tasks of the sortie is "included" in that minimum value.

TABLE 4-1

CALCULATION OF SORTIE PROBABILITY OF SUCCESS

PARAMETER / TASK	CC	DF	LS	MN	TW	TASK PROB OF SUCCESS
TASK 1	1.0	.99	.95	1.0	1.0	0.94
TASK 2	1.0	.99	.95	0.9	1.0	0.85
TASK 3	1.0	.99	.95	0.95	1.0	0.89
TASK 4	1.0	.99	.95	1.0	0.95	0.89
TASK 5	1.0	.99	.95	0.85	1.0	0.80
MINIMUM PARAMETER VALUE	1.0	.99	.95	.85	.95	.51 / .76

The minimum values are multiplied together as shown in Table 4-1. The value obtained is called a sortie probability of success.

As can be seen in Table 4-1, the product of the task parameter values provides the task probability of success (horizontal multiplication). Selecting the minimum value of each parameter from the matrix (vertically), and multiplying these values together provides a more realistic value for sortie performance. In Table 4-1, this value is 0.76 or 76 percent. Multiplying each task probability of success together exceeds the "one time" influence of the parameter on the sortie, resulting in an unrealistically low value for sortie probability of success. In this example, such an improper procedure would cause the sortie probability of success to be 0.51 or 51 percent.

4.2 Elimination of Unrealistic Sorties

Since sorties are the individual paths of a flow chart scenario, and since most scenarios will make use of iterative or feedback loops, it is theoretically possible to have sorties which would take an unreasonable amount of time to complete.

To eliminate consideration of these improbable sorties in both sortie evaluation and later in scenario evaluation, running totals of the time to complete each task and the fuel consumed during the performance of each task are tallied. If the time to complete a sortie exceeds a user inputed Maximum Sortie Duration time, that particular sortie is eliminated from further consideration. Likewise, if the fuel consumed during the course of completing a sortie exceeds the fuel capacity of the craft under consideration, the same procedure is followed and the sortie is not evaluated. Regarding this fuel consumption procedure, the user can make use of an additional input in his scenario, a Range Fraction input, which is his limitation of the fraction of the total craft fuel capacity that may be used in completing any sortie.

Thus, those sorties that exceed the endurance or range of the craft are eliminated from the evaluation calculations and only realistic sorties are considered.

The Craft/Task Evaluation element of the model produces for each completed sortie, a listing of the Functional Task Groups and individual tasks of the sortie, together with the task times, task fuel consumption and task probability of success values. In addition, this Sortie Output page lists the sortie probability of success and frequency of occurrence values. A typical Sortie Output page is shown in Table 4-2.

4.3 Sortie Summary

Two different numbers are associated with any given sortie: the sortie frequency of occurrence and the sortie probability of success. The former is determined from the user's choices of the decision point probabilities in the process of scenario construction, and illustrates how often one would expect the particular sortie to occur in relation to the other sorties of the scenario. The sortie probability of success is calculated according to the procedures just previously discussed in Section 4.1, Sortie Evaluation Procedure.

If these two quantities, representative of occurrence and success, for any given sortie are multiplied together, a number indicative of sortie successful occurrence is obtained. This value, a weighted sortie probability of success reflecting both the expected sortie occurrence and the degree of craft success, provides a single measure which one can use to gauge craft performance in one sortie to craft performance in another sortie of the same scenario. Thus, this number offers a better insight of total craft performance at the sortie level than either of its two components along. It is also utilized in higher level evaluations as discussed in Section 5.0, SCENARIO EVALUATIONS.

In addition to this weighted sortie probability of success, summaries can also be made of the two quality indicators used in further evaluating craft performance of tasks, i.e., time to complete and fuel consumed. For any given sortie, the time to complete the entire sequence of tasks is the sum of the individual task times, and the total fuel consumed is the sum of the fuel consumed while performing each task.

The sortie summary information above is outputted from the CREE Model computer program as illustrated in Table 4-3.

TABLE 4-2

TYPICAL SORTIE OUTPUT PAGE

SAR SCENARIO 1
SORTIE NUMBER 23

OPERATIONAL REQUIREMENTS:	SELECTED CRAFT:
MAXIMUM DURATION 12.0 HOURS	PLANING CRAFT
RANGE FRACTION 0.90	DISPLACEMENT 96 TONS
VISIBILITY GOOD	DESIGN SPEED 40 KNOTS
AVERAGE SEA STATE 4.0	FUEL FRACTION 0.50

GROUP NAME	TASK NAME	LOCATION CODE	TASK TIME (HRS)	TASK FUEL (GALS)	TASK POS
		1			
STEAM		150201			
	*DASH	150203	1.2	504	0.80
		150202			
		7			
PATROL		70101			
	*SLOW PATROL	70102	4.0	999	0.80
		8			
STEAM		150301			
	*DASH	150303	0.6	252	0.80
		150302			
		3			
SAR SEARCH		100101			
		100104			
	*SEARCH DSTR UNIT: FOUND	100102	2.4	589	0.71
		4			
ASSIST		10101			
	*LAUNCH SMALL BOAT	10106	0.1	2	0.45
	*ON BOARD ASSISTANCE	10107	0.5	11	0.80
	*RETRIEVE SMALL BOAT	10102	0.1	2	0.45
		5			
		6			
STEAM		150401			
	*TRANSIT	150402	0.9	330	0.80
		2			

TIME TO COMPLETE SORTIE (HRS)	9.8		
FUEL CONSUMED IN SORTIE (GALS)		2691	
SORTIE PROBABILITY OF SUCCESS			0.4483
SORTIE FREQUENCY OF OCCURRENCE			0.0075

TABLE 4-3

TYPICAL SORTIE SUMMARY PAGE

************* SORTIE SUMMARY *************

SAR SCENARIO 1

OPERATIONAL REQUIREMENTS:	SELECTED CRAFT:
MAXIMUM DURATION 12.0 HOURS	PLANING CRAFT
RANGE FRACTION 0.90	DISPLACEMENT 96 TONS
VISIBILITY GOOD	DESIGN SPEED 40 KNOTS
AVERAGE SEA STATE 4.0	FUEL FRACTION 0.50

FRACTION OF SCENARIO COMPLETED 0.9545

SORTIE NO.	SORTIE TIME (HRS)	SORTIE FUEL (GALS)	FREQUENCY OF OCCURRENCE	SORTIE PROBABILITY OF SUCCESS	SORTIE SUCCESSFUL OCCURRENCE
1	7.7	1880	0.0584	0.6586	0.0384
2	7.7	1867	0.0097	0.6671	0.0065
3	6.0	1614	0.0292	0.6671	0.0195
4	5.6	1448	0.0243	0.6671	0.0162
5	7.3	1871	0.1459	0.5790	0.0845
6	7.3	1859	0.0243	0.5865	0.0143
7	5.6	1605	0.0730	0.5865	0.0428
8	5.2	1440	0.0608	0.5865	0.0357
9	7.3	1871	0.0876	0.4425	0.0387
10	7.3	1859	0.0146	0.4483	0.0065
11	5.6	1605	0.0438	0.4483	0.0196
12	5.2	1440	0.0365	0.4483	0.0164
13	10.1	2833	0.0920	0.7148	0.0658
14	10.6	2865	0.0060	0.6671	0.0040
15	10.2	2700	0.0050	0.6671	0.0033
16	12.0	3123	0.0300	0.5790	0.0174
17	11.9	3111	0.0050	0.5865	0.0029
18	10.3	2857	0.0150	0.5865	0.0088
19	9.8	2691	0.0125	0.5865	0.0073
20	12.0	3123	0.0180	0.4425	0.0080
21	11.9	3111	0.0030	0.4483	0.0013
22	10.3	2857	0.0090	0.4483	0.0040
23	9.8	2691	0.0075	0.4483	0.0034
24	7.8	2024	0.0071	0.6586	0.0046
25	6.7	1846	0.0030	0.7046	0.0021
26	6.7	1846	0.0151	0.7046	0.0107
27	7.8	2023	0.0030	0.5790	0.0018
28	6.6	1846	0.0013	0.5865	0.0008
29	6.6	1846	0.0065	0.5865	0.0038
30	10.1	2793	0.0080	0.6586	0.0053
31	10.1	2780	0.0013	0.6671	0.0009
32	8.4	2527	0.0040	0.6671	0.0027
33	8.0	2361	0.0033	0.6671	0.0022
34	9.8	2784	0.0200	0.5790	0.0116

5.0 SCENARIO EVALUATION

Scenarios are constructed by the user when he sequences functional task groups, or modules representing various operational activities, together in a flow chart format. This flow chart or scenario represents a Coast Guard program or mission. The extent to which a scenario represents a portion of Program, a complete Program, or a mix of portions of several Programs, is only dictated by the user's choice of the various operational activities sequenced together.

Prior to using the CREE Model, the user has some objective, goal or mission that he wishes to accomplish, and feels that utilization of watercraft at least represents one way of performing the job. The scenario is the logical representation of the operational activities conducted by a craft that he feels will accomplish his objective. The user may be interested in evaluating one or more types of craft in a well-known, defined and accepted concept of operations or deployment scheme, or he may be interested in evaluating one or more "experimental" concepts of operations with one specific vessel. No matter what avenue he wishes to pursue, the evaluation of the craft performance in the scenario will provide a solution.

The process of evaluating performance within a scenario in the CREE Model is based upon the previously developed task and sortie evaluations. This section describes the various aspects of this scenario evaluation and culminates in the presentation of the quantitative results in a format enabling the user to directly relate performance to his objectives or goals.

5.1 Fraction of Scenario Completed

As described earlier, sorties are a sequence of tasks, or complete paths of a flow chart scenario. Any scenario therefore can be viewed as a set of sorties, all of which, each in their own way, contribute to the user's objectives or goals.

Recalling that each sortie has a frequency of occurrence* associated with it, plus recalling that some sorties are eliminated from evaluation due to the time and fuel limitations of the craft, it is evident that the total frequency of occurrence of all of the completed or remaining sorties represent the fraction of the scenario that is completed by the craft.

The significance of this fraction lies in the fact that it is a simple representation of the total amount of the job described by the scenario that can be completed when constrained only by time and fuel considerations. As such, when comparing two different craft, it indicates which craft has a greater capacity for work, or if considering one craft and two different scenarios, indicates which scenario or concept of operations represents the more optimum employment of the given craft.

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*Sorties involving searching use a modified search theory approach to determine success/failure probabilities. These probabilities are in effect frequencies of occurrence for finding or not finding. See Appendix D for detailed development.

5.2 Average Sortie Probability of Success

Since a scenario is, in one respect, a completed set of sorties, and since craft performance in each sortie can be described by a weighted probability of success (see Section 4.3, Sortie Summary), the indicator for evaluating performance in the whole scenario is the average of those weighted values of sortie probability of success.

The average sortie probability of success is, as the name suggests, an average of the expected performance in each sortie. Viewed from another aspect, it can also be considered as the probability of successfully completing the scenario, because it "describes the average sortie."

The value of the average sortie probability of success is determined by adding together all of the probabilities of successful sortie completion,. These are, as described in Section 4.3, Sortie Summary, the products of sortie occurrence and sortie success. Notationally, the average sortie probability of success is defined as:

$$\text{Average Sortie Probability of Success} \equiv \sum_{i=1}^{N} \text{Sortie}_i\ (\text{freq}) * \text{Sortie}_i\ (\text{pos})$$

where: Sortie_i (freq) is the Frequence of Occurrence in the i^{th} sortie

and Sortie_i (pos) is the Probability of Success of the i^{th} sortie

The average sortie probability of success, or the probability of successfully completing the scenario (depending upon how one chooses to describe this value) is indicative of the quantity of work that a craft can be expected to perform in a scenario. This considers both the time and fuel limitations of the craft, and the degradation in craft performance due to other limitations in craft capability or environmental constraints of the operational requirements. The time and fuel limitations of the craft are brought into the picture by the consideration of only completed sorties; and the degradation in craft performance is represented by the incorporation of the sortie probability of success values into the calculations.

In summary, the average sortie probability of success provides the user with a single number indicative of how much a craft can be expected to successfully complete in the scenario he constructed.

Table 5-1, Typical Scenario Overall Results, illustrates the average sortie probability of success and an average of the sortie times and fuel consumptions.

5.3 The Average Sortie

The foregoing section discussed a figure of merit indicative of how much of a scenario a craft can be expected to complete, and stated that this value could be considered as the "average sortie probability of success." The question that naturally arises at this point is, "what does this average sortie lool like?"

Since all sorties of the scenario are different, the average sortie must consist of a little of each completed sortie. This average sortie is not an identifiable completed path of the scenario, but rather a single sortie that has been created by a mathematical reduction of the entire successfully completed scenario.

The average successfully completed sortie contains every task that has been successfully completed in the scenario. In addition, each task in this average sortie has associated with it a fractional coefficient representing the average number of times the task is successfully completed in the scenario. Functionally, these coefficients for each task are expressed as follows:

$$\text{Coef}_{\text{TASK K}} = \begin{array}{c}\text{Average number of time} \\ \text{Task K is completed} \\ \text{successfully in the} \\ \text{scenario}\end{array} = \sum_{i=1}^{N} \text{Sortie}_i \text{ (freq)} * (\text{\# Task K})_i$$

where
- N is the total number of sorties that have been completed
- Sortie_i (freq) is the frequency of occurrence of the i^{th} sortie

and
- $(\text{\# Task K})_i$ is the number of times that Task K is completed in the i^{th} sortie

Table 5-2 is a simplified example of calculating the coefficients of the average successfully completed sortie to provide one with a more intuitive feel of this hypothetical sortie. The table shows, for example, that on each day (or each time the craft attempts a sortie) we can expect it to complete 200 Escorts. This means that once in every five attempted sorties, the craft will successfully complete an Escort. Figure 5-1, Typical Scenario Overall Results, illustrates the CREE Model computer program output format for the average sortie task composition.

5.4 Long-Term Operational Evaluation

The average successfully completed sortie developed in the preceding section not only enables the user to quickly examine the scope of successful craft performance in his scenario, but it also provides a convenient mechanism for a simple forecast of expected craft performance in long-term operations.

TABLE 5-1

TYPICAL SCENARIO OVERALL RESULTS PAGE

************* SCENARIO OVERALL RESULTS *************

SAR SCENARIO 1

OPERATIONAL REQUIREMENTS:	SELECTED CRAFT:
MAXIMUM DURATION 12.0 HOURS	PLANING CRAFT
RANGE FRACTION 0.90	DISPLACEMENT 96 TONS
VISIBILITY GOOD	DESIGN SPEED 40 KNOTS
AVERAGE SEA STATE 4.0	FUEL FRACTION 0.50

PERCENT OF SCENARIO COMPLETED 95.4

PROBABILITY OF SUCCESSFULLY COMPLETING SCENARIO 0.5514

SPECIFICATIONS OF THE AVERAGE SORTIE:

TIME TO COMPLETE AVERAGE SORTIE 7.7 HRS

FUEL CONSUMED IN AVERAGE SORTIE 2068.6 GALS

TASK COMPOSITION IN AVERAGE SORTIE:

TASK CODE	TIMES COMPLETED	TASK NAME
ON SCENE:		
BRD	0.25	BOARD
GAS	0.13	GENERAL ASSISTANCE
LSB	0.11	LAUNCH SMALL BOAT
OBA	0.36	ON BOARD ASSISTANCE
RBP	0.25	RETRIEVE BOARDING PARTY
RSB	0.11	RETRIEVE SMALL BOAT
REDUCED SPEED:		
SDU	0.51	SEARCH FOR DISTRESSED UNIT
SES	0.04	SLOW ESCORT
SPT	0.08	SLOW PATROL
TOW	0.22	TOW
CRUISE SPEED:		
PAT	0.06	PATROL
TPE	0.11	TRANSPORT PEOPLE
TRA	0.18	TRANSIT
FLANK SPEED:		
DSH	0.66	DASH

TABLE 5-2

EXAMPLE CALCULATION OF COEFFICIENTS FOR AVERAGE SUCCESSFUL SORTIE

SORTIE	1	2	3	4	5	
Sortie Frequency of Occurrence	.30	.25	.20	.15	.10	
Sortie Probability of Success	.95	.80	1.0	.70	0.0	
Sortie Successful Occurrence	.285	.200	.200	.105	.000	
TASKS IN SORTIES						
Transit	2	0	1	2	2	
Interdict	0	1	1	0	0	
Search	0	1	1	1	1	
Identify	36	12	0	12	24	
Inspect	4	1	0	2	2	
Escort	0	1	0	0	0	
(#Tasks) x (Sortie Successful Occurrence)						Avg. Sortie Contains
Transit	.57	0	.200	.210	0	.980
Interdict	0	.200	.200	0	0	.400
Search	0	.200	.200	.105	0	.505
Identify	10.26	2.40	0	1.26	0	13.92
Inspect	1.140	.200	0	2.10	0	.305
Escort	0	.200	0	0	0	.200

Recalling the earlier statement that any sortie can be considered to be a daily activity, such as a typical SAR case or harbor pollution patrol, it is evident that the average successfully completed sortie can also be considered as a single day's operation, in this case some hypothetical average day. If the user is interested in determining how much work can be expected to be accomplished in a given time frame, he can multiply each task coefficient of this average sortie by the number of sorties desired or the number of days deployed. This produces the actual number of times each task is successfully completed in the long-term time period.

Since "average times" to complete the tasks and "average fuel consumptions" for each task are also available, the user is also provided with quality indicator information along with the quantity forecast.

5.5 Important Tasks and Program Goals

Among the tasks used in constructing a scenario, some tasks contribute more towards the accomplishment of the user's particular goals or objectives than other tasks. The number of successful completions of these more important tasks in a given time frame provide an immediate measure of craft effectiveness in achieving the operational objective.

In utilizing this model, the user should be able to specify which tasks do contribute directly towards achieving those objectives, or conversely, be able to specify how much effort is sufficient to achieve his objectives. In ELT, for example, he should know how many identifications and inspections are sufficient to satisfy the objective of gathering data. If so, the user can then directly relate the output of the model, number of successful task completions, to his goals or objectives. In cases where the user cannot specify the number of task completions which will satisfy an objective, he still can use the calculated values for the number of task completions as a relative indication of craft success.

To provide flexibility for the various Programs, the user can select those tasks he feels to be important in his program and highlight them in the outputed evaluation for a specified number of days of operation. The model calculates and tabulates the number of these successfully completed important tasks. This is illustrated in Table 5-3, Typical Scenario Evaluation page.

TABLE 5-3

TYPICAL SCENARIO EVALUATION PAGE

```
************** SCENARIO EVALUATION **************

            SAR SCENARIO  1

OPERATIONAL REQUIREMENTS:                 SELECTED CRAFT:

MAXIMUM DURATION    12.0 HOURS            PLANING CRAFT
RANGE FRACTION 0.90                       DISPLACEMENT    96 TONS
VISIBILITY GOOD                           DESIGN SPEED 40 KNOTS
AVERAGE SEA STATE 4.0                     FUEL FRACTION 0.50

   IMPORTANT TASKS COMPLETED IN  180 DAYS OF OPERATION

        TASK      TIMES        TASK
        CODE    COMPLETED      NAME

  ON SCENE:
        GAS        23        GENERAL ASSISTANCE
        OBA        64        ON BOARD ASSISTANCE

  REDUCED SPEED:
        SPT        15        SLOW PATROL
        TOW        40        TOW

  CRUISE SPEED:
        PAT        11        PATROL
        TPE        21        TRANSPORT PEOPLE

  FLANK SPEED:
        NO IMPORTANT TASKS SPECIFIED
```

6.0 SUMMARY OF CREE MODEL EVALUATION PROCEDURE

Table 6-1 summarizes the entire evaluation procedure used in the CREE Model. It lists input information and evaluation criteria for the various levels of possible evaluations, beginning with craft characteristics, proceeding through tasks, sorties and scenarios, and ending up with Programs. In addition, this table shows which computer output pages correspond to which level of evaluation and where typical or format samples can be located in this report.

TABLE 6-1

SUMMARY OF CREE MODEL EVALUATION

LEVEL OF EVALUATION	INPUT TO EVALUATION	EVALUATION CRITERIA	LOCATION IN MODEL OUTPUT
CRAFT	Craft Type Craft Size Craft Speed Fuel Fraction	Craft Characteristics	Craft Characteristics Output Page (Table 2-1)
TASK	Craft Characteristics and Operational Requirements and Tasks	Parameters	Parameter Output Page (Table 3-4)
		Task Probabilities of Success	Task POS Output Page (Table 3-5)
SORTIE SCENARIO	Above and Scenario	Task Probability of Success Task Time Task Fuel	Sortie Output Page (Table 4-2)
		Sortie Probability of Success Sortie Frequency of Occurrence Sortie Time & Fuel	Sortie Output Page (Table 4-2) Sortie Summary Page (Table 4-3)
		% Scenario Completed Probability of Successfully Completing Scenario Average Sortie Composition and Average Time & Fuel	Scenario Overall Results Page (Table 5-1)
PROGRAM	Above and User Chosen Tasks and Time Frame	Important Tasks Completed in $\underline{X}$ Days of Operation	Scenario Evaluation Page (Table 5-3)

LENGTH
-VS-
DISPLACEMENT

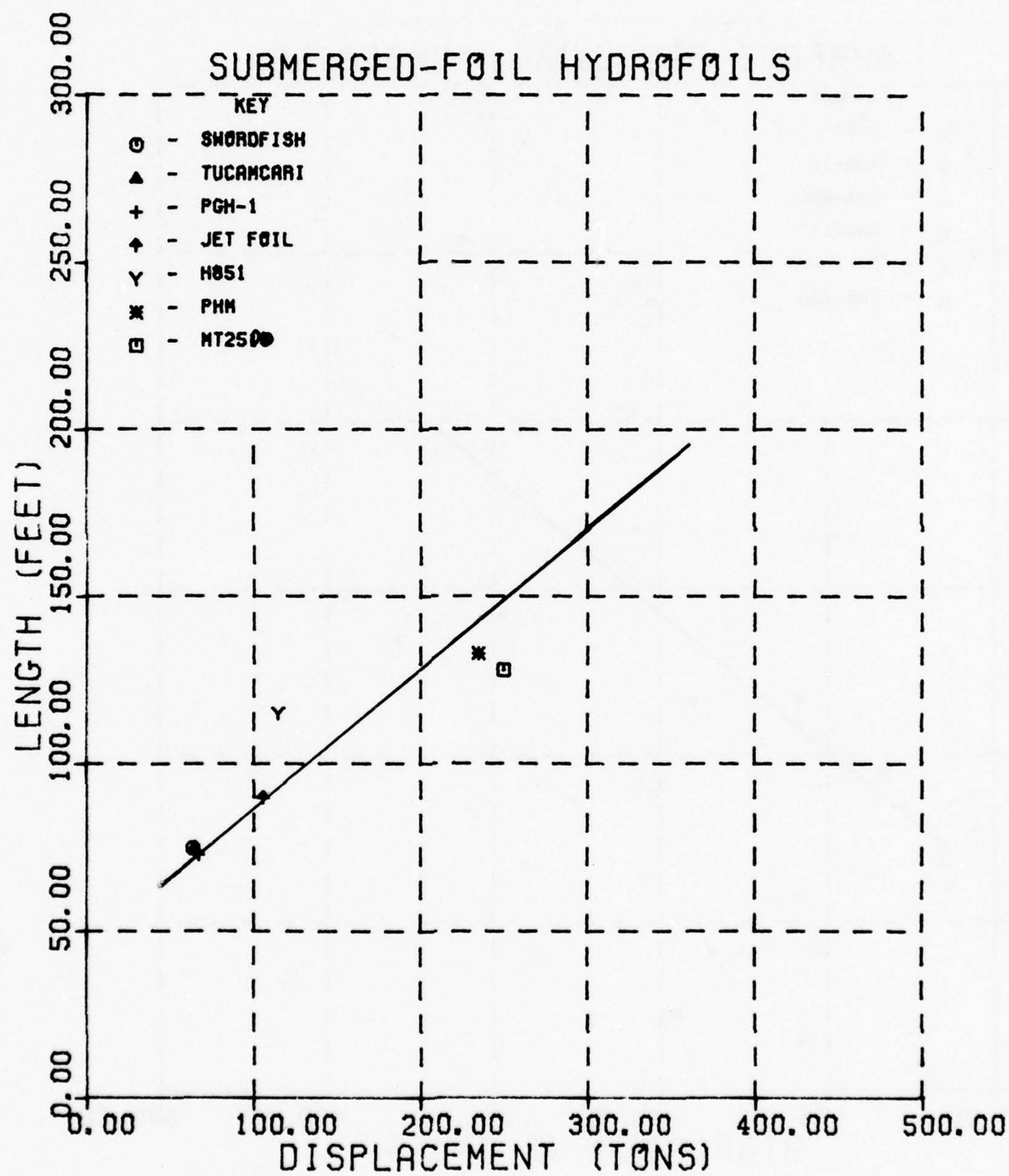

FIGURE A-1

LENGTH
-VS-
DISPLACEMENT

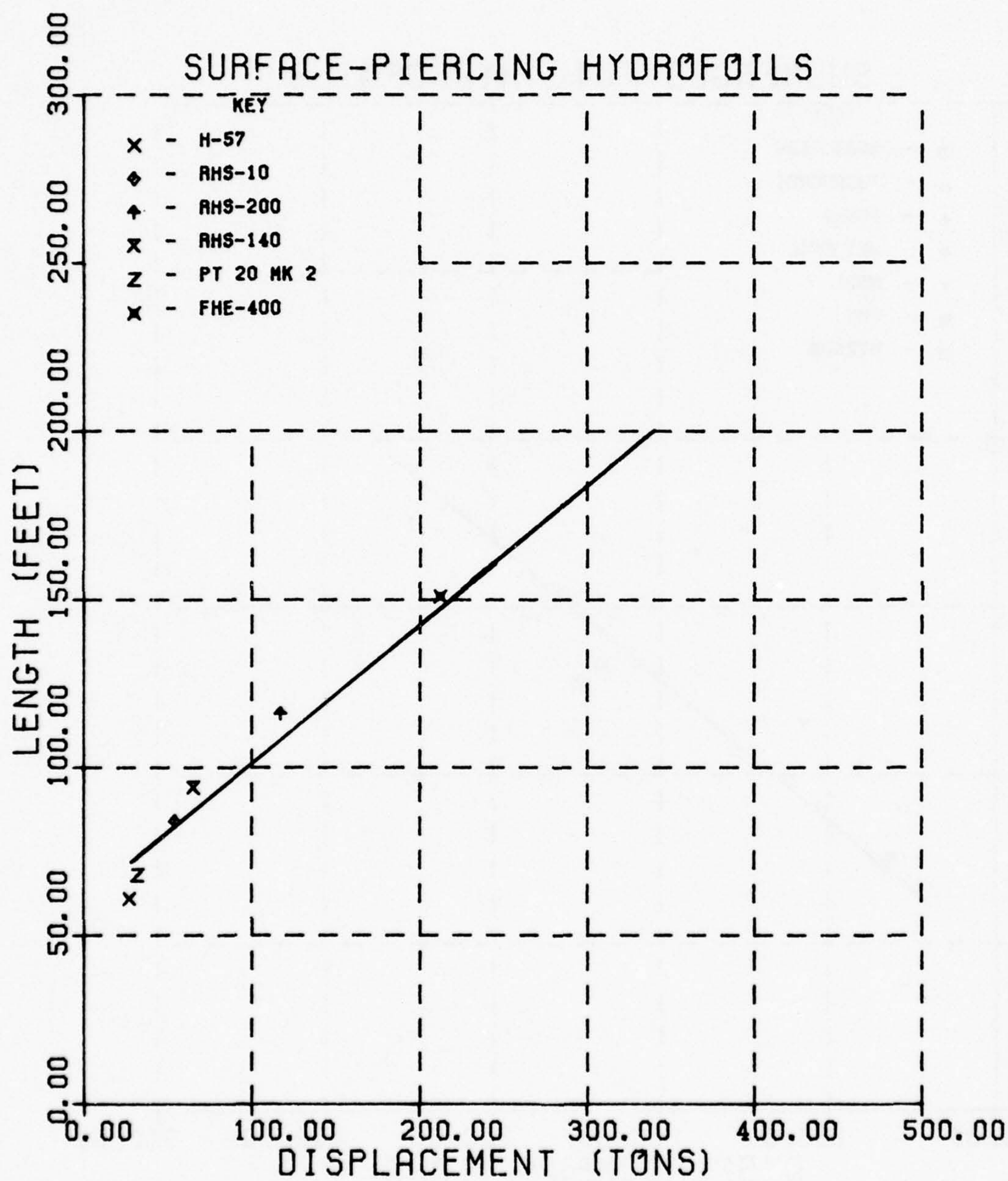

FIGURE A-2

LENGTH
-VS-
DISPLACEMENT

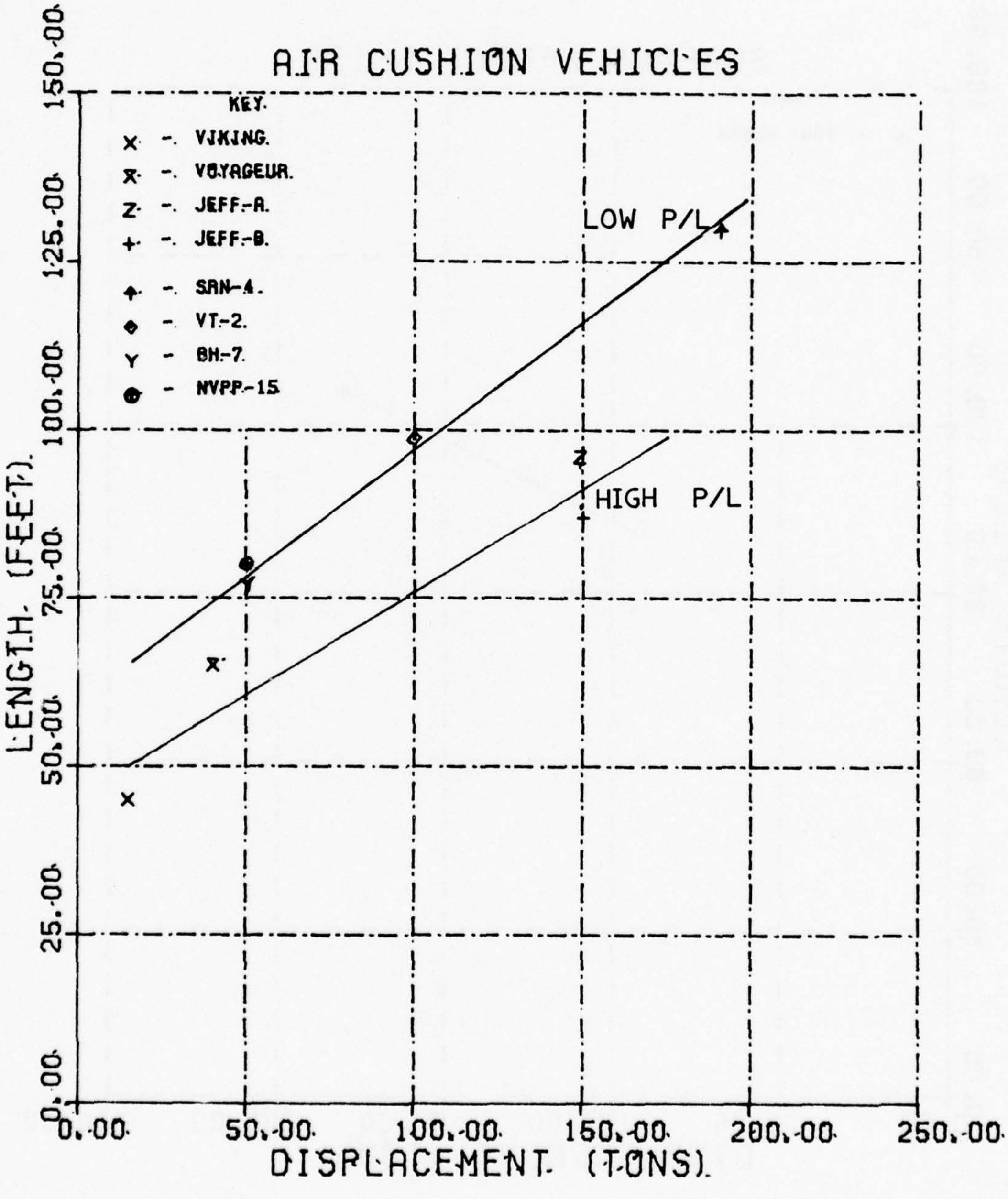

FIGURE A-3

LENGTH
-VS-
DISPLACEMENT

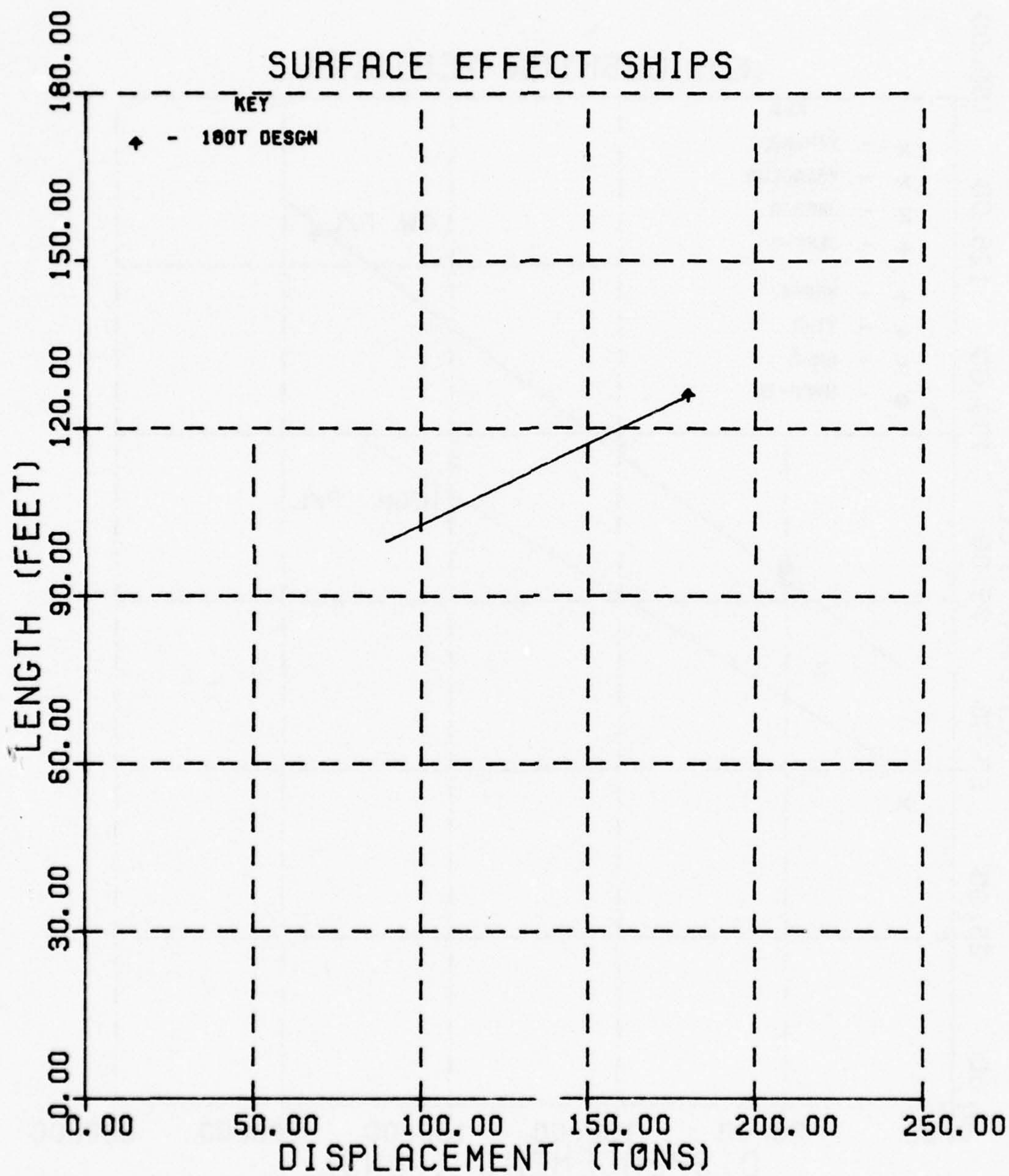

FIGURE A-4

LENGTH
-VS-
DISPLACEMENT

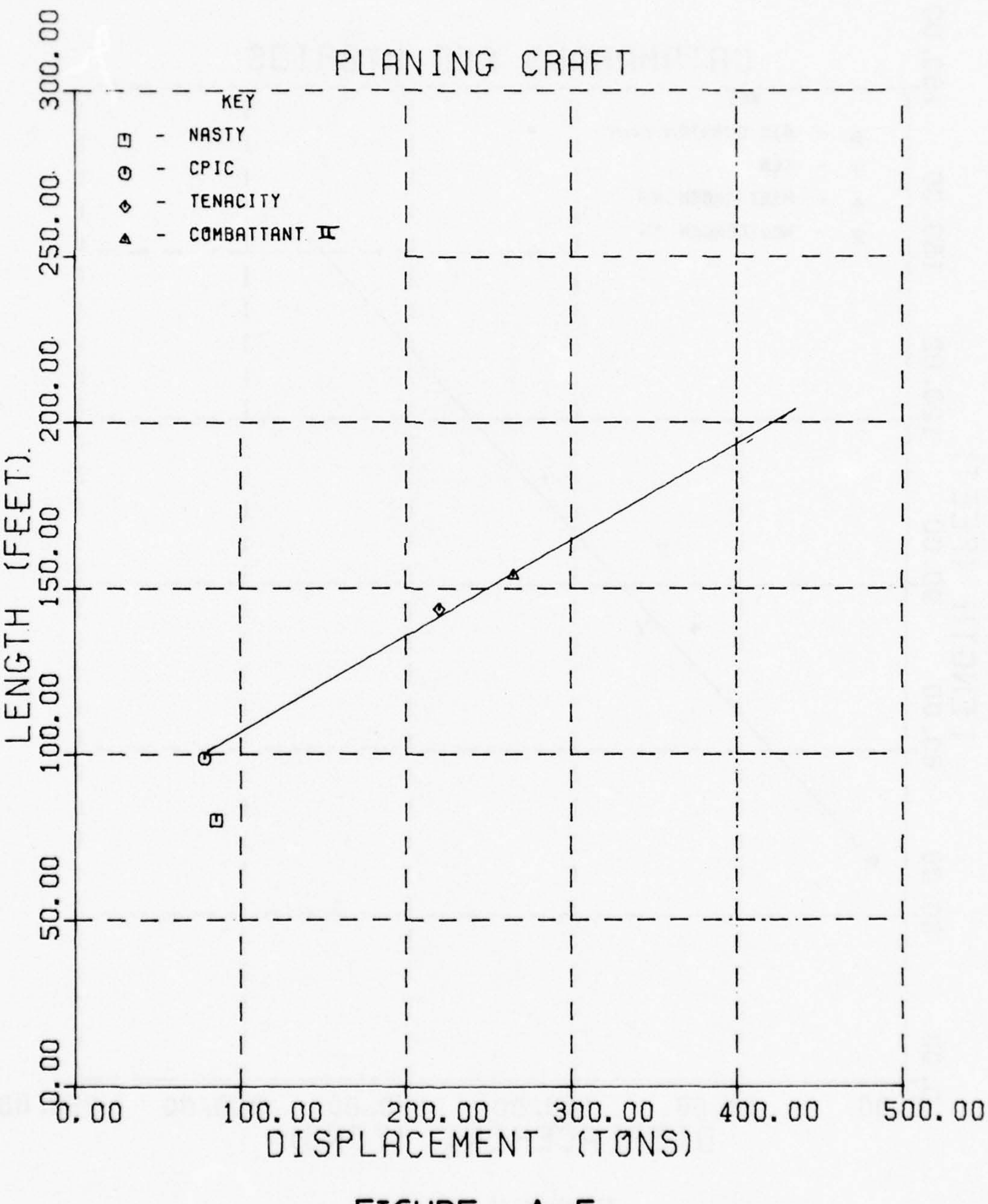

FIGURE A-5

LENGTH
-VS-
DISPLACEMENT

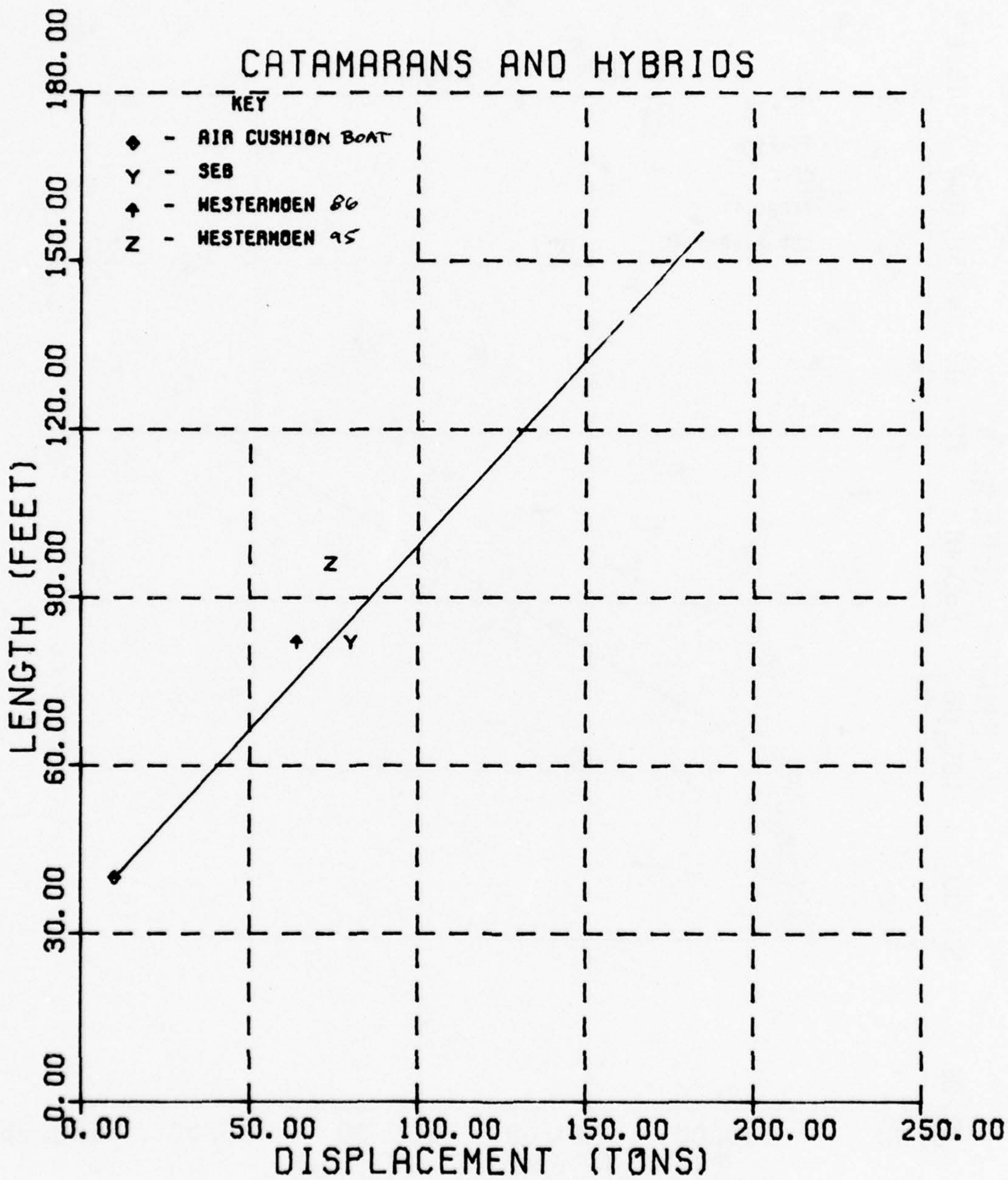

FIGURE A-6

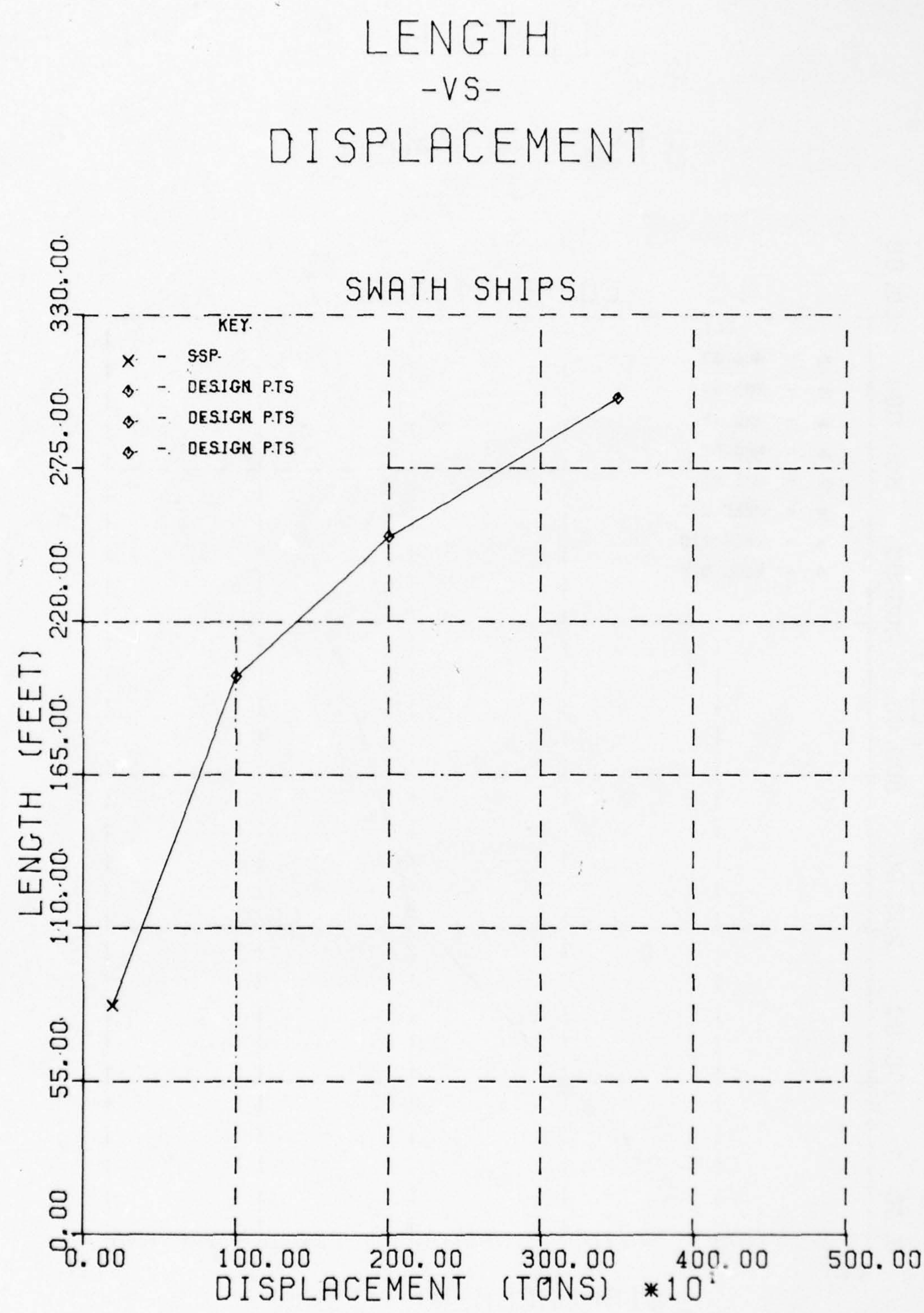
LENGTH
-VS-
DISPLACEMENT
SWATH SHIPS
KEY
SSP
DESIGN PTS
DESIGN PTS
DESIGN PTS
LENGTH (FEET)
DISPLACEMENT (TONS) *10

FIGURE A-7

LENGTH
-VS
DISPLACEMENT

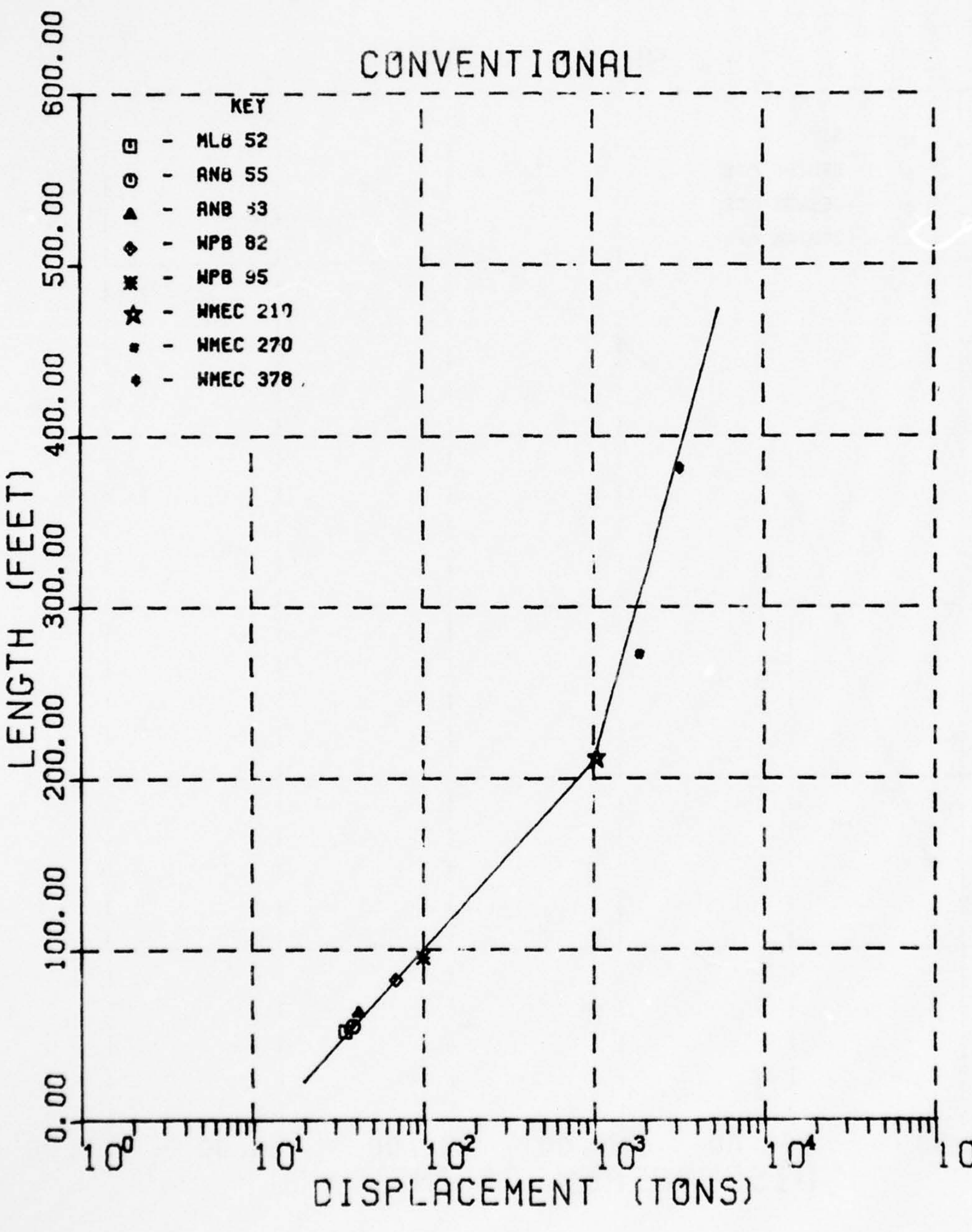

FIGURE A-8

TOTAL USEFUL PAYLOAD
-VS-
DISPLACEMENT

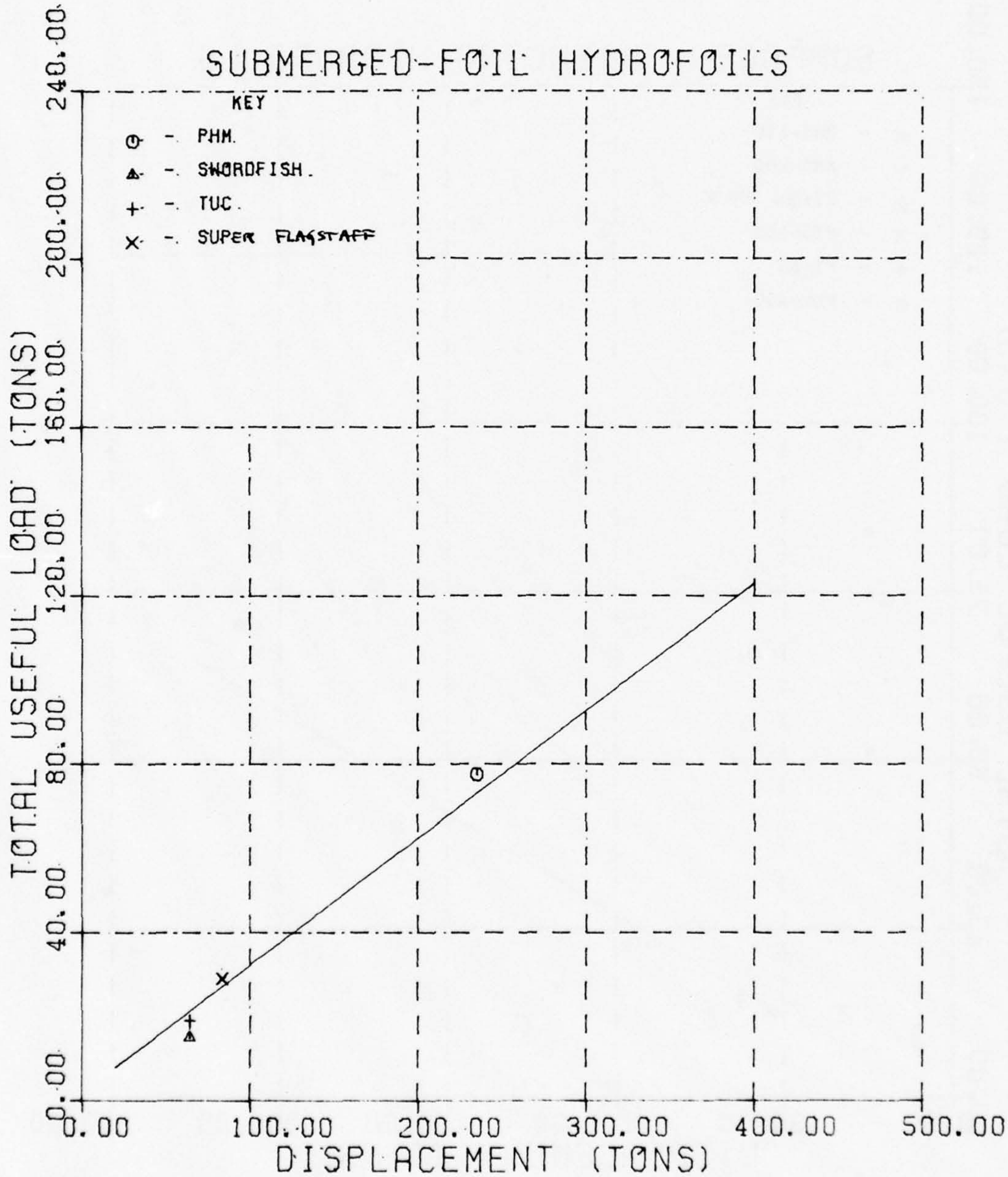

FIGURE A-9

TOTAL USEFUL PAYLOAD
-VS-
DISPLACEMENT

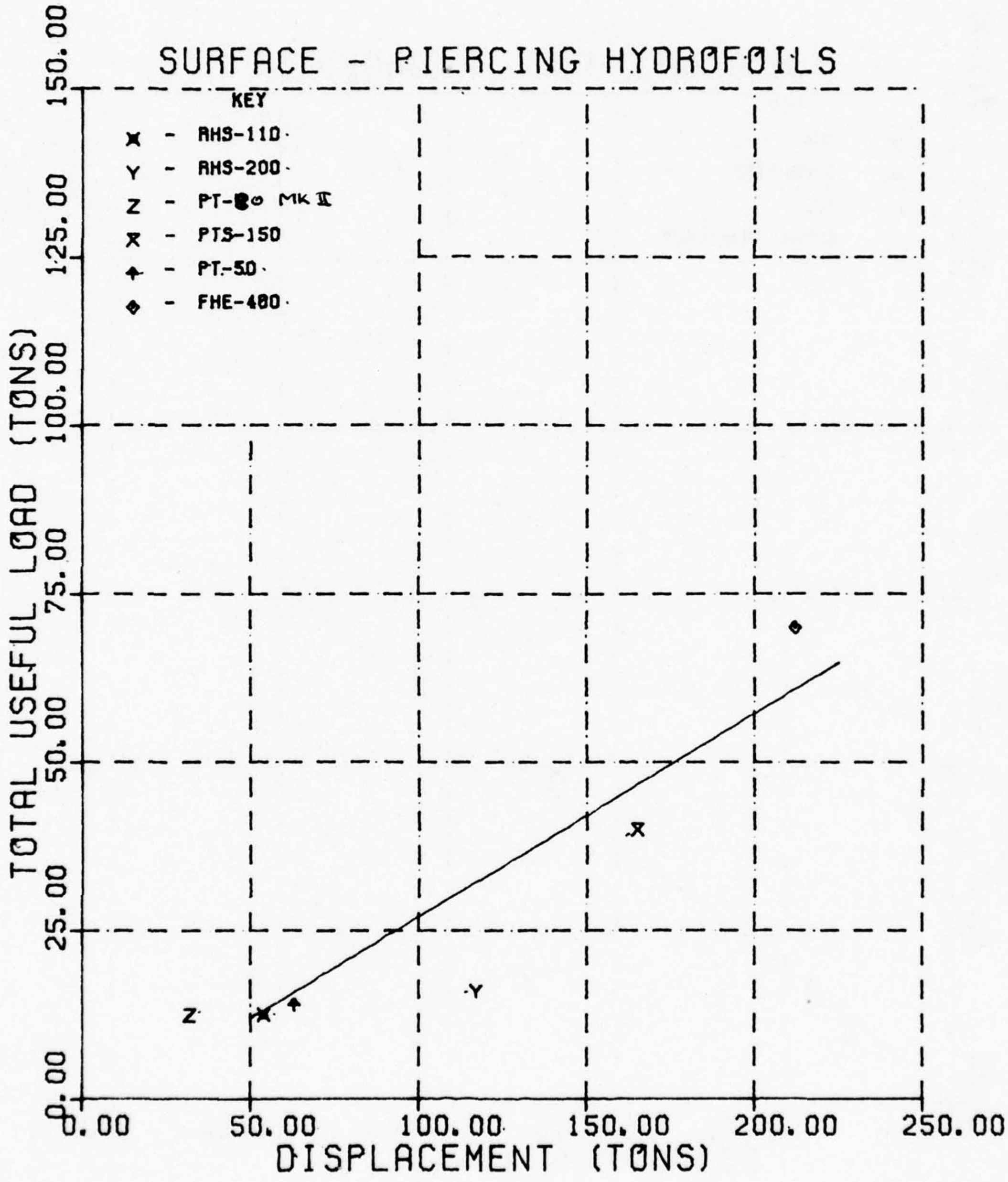

FIGURE A-10

TOTAL USEFUL PAYLOAD
-VS-
DISPLACEMENT

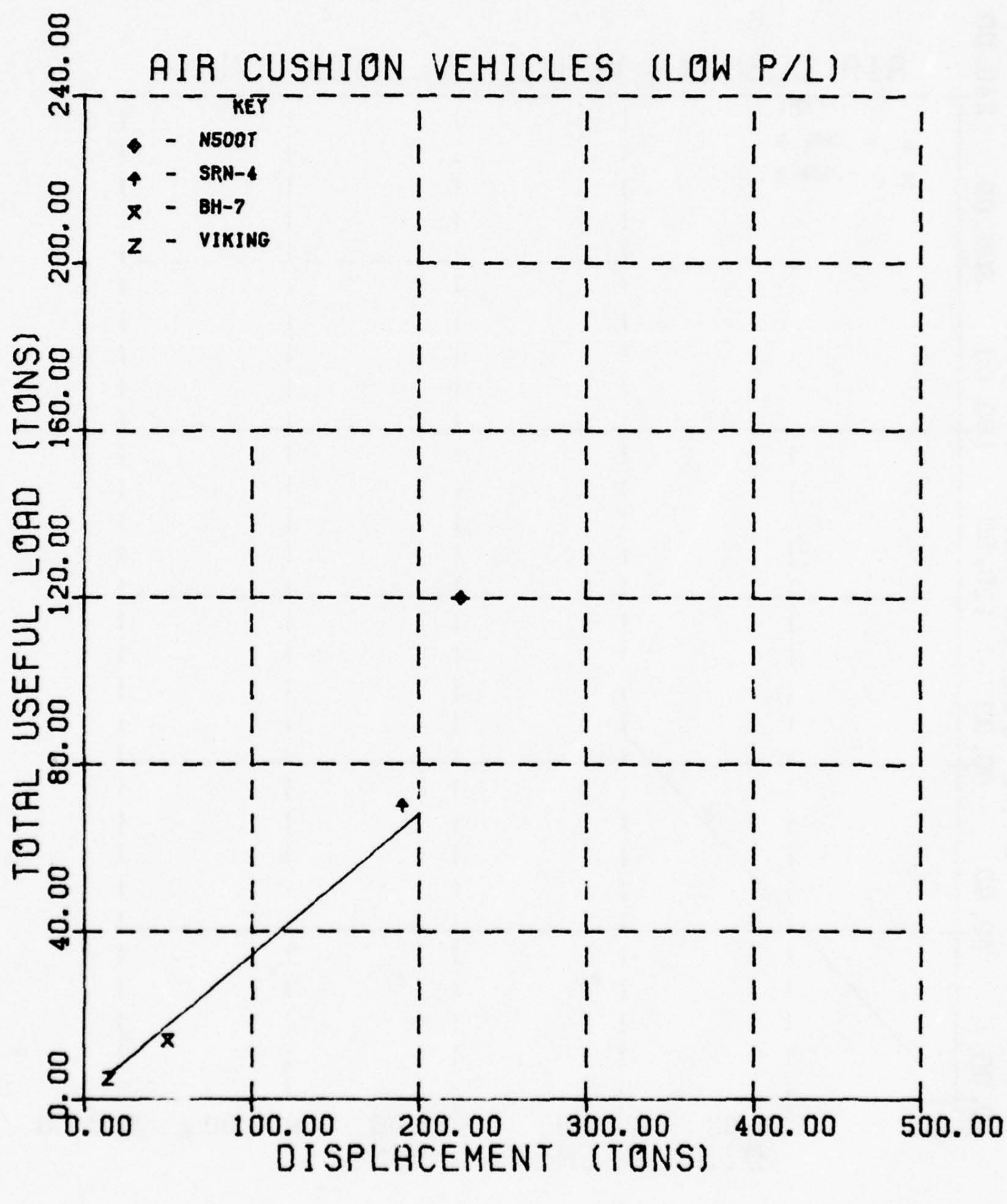

FIGURE A-11

TOTAL USEFUL PAYLOAD
-VS-
DISPLACEMENT

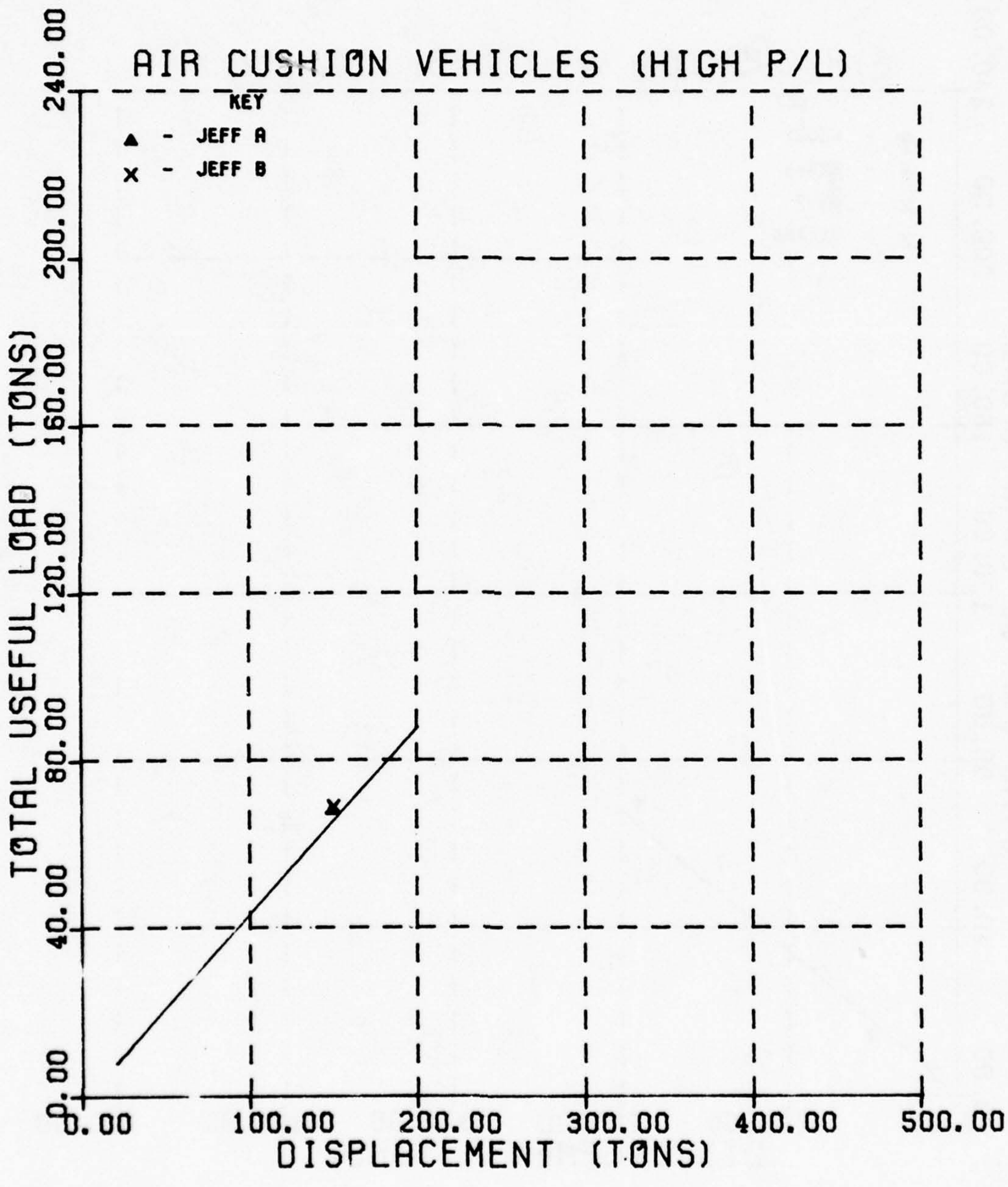

FIGURE A-12

TOTAL USEFUL PAYLOAD
-VS-
DISPLACEMENT

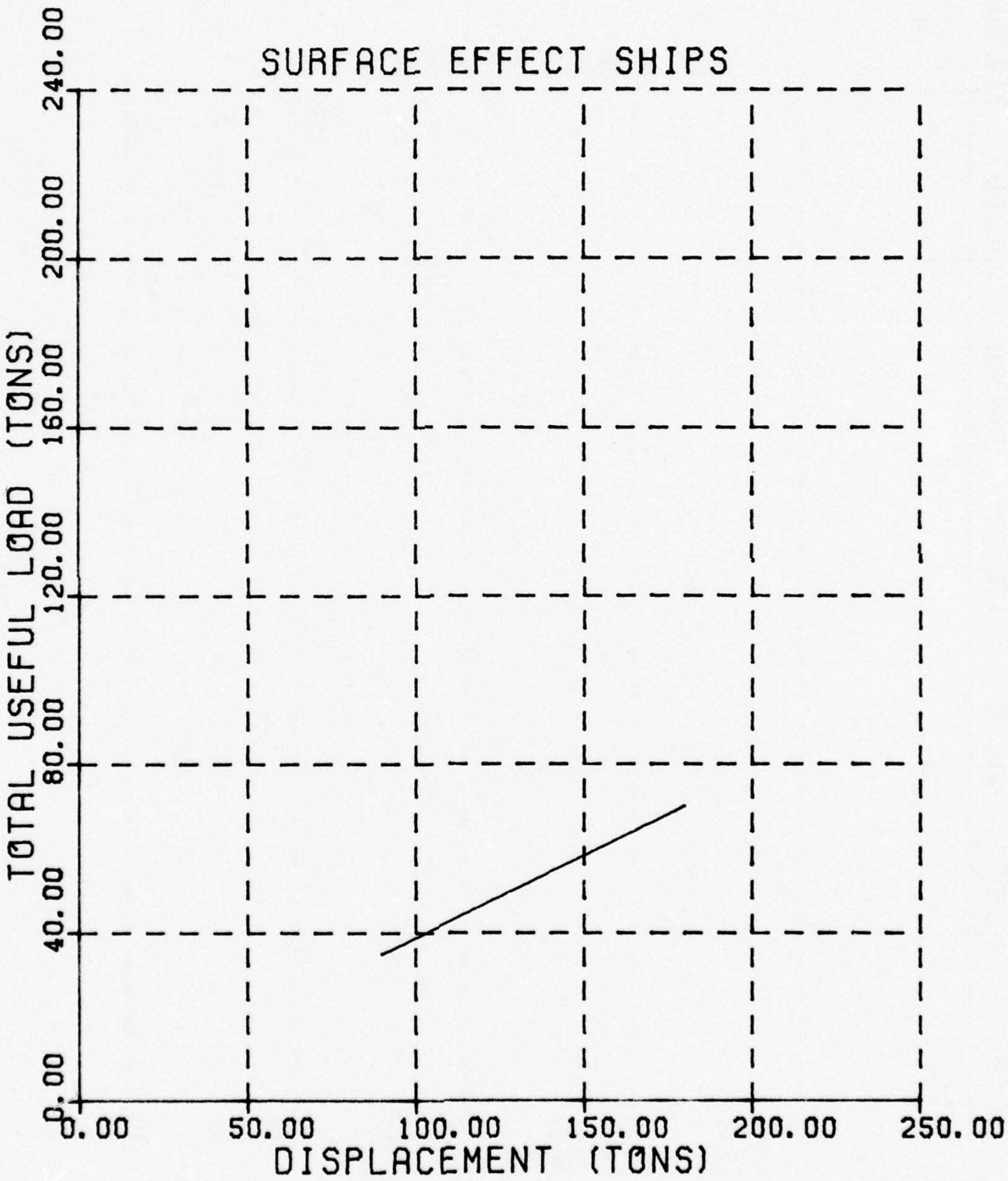

FIGURE A-13

TOTAL USEFUL PAYLOAD
-VS-
DISPLACEMENT

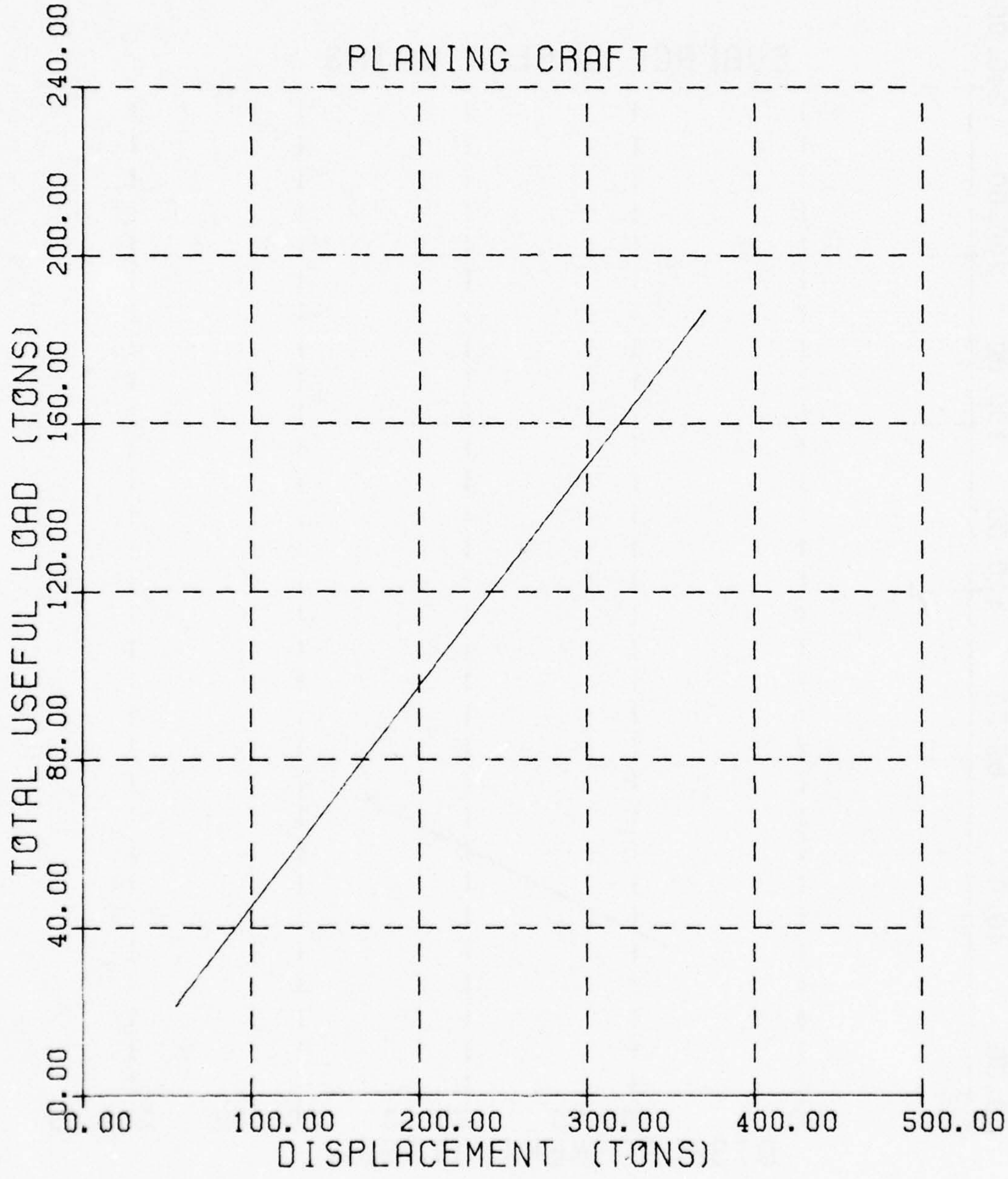

FIGURE A-14

TOTAL USEFUL PAYLOAD
-VS-
DISPLACEMENT

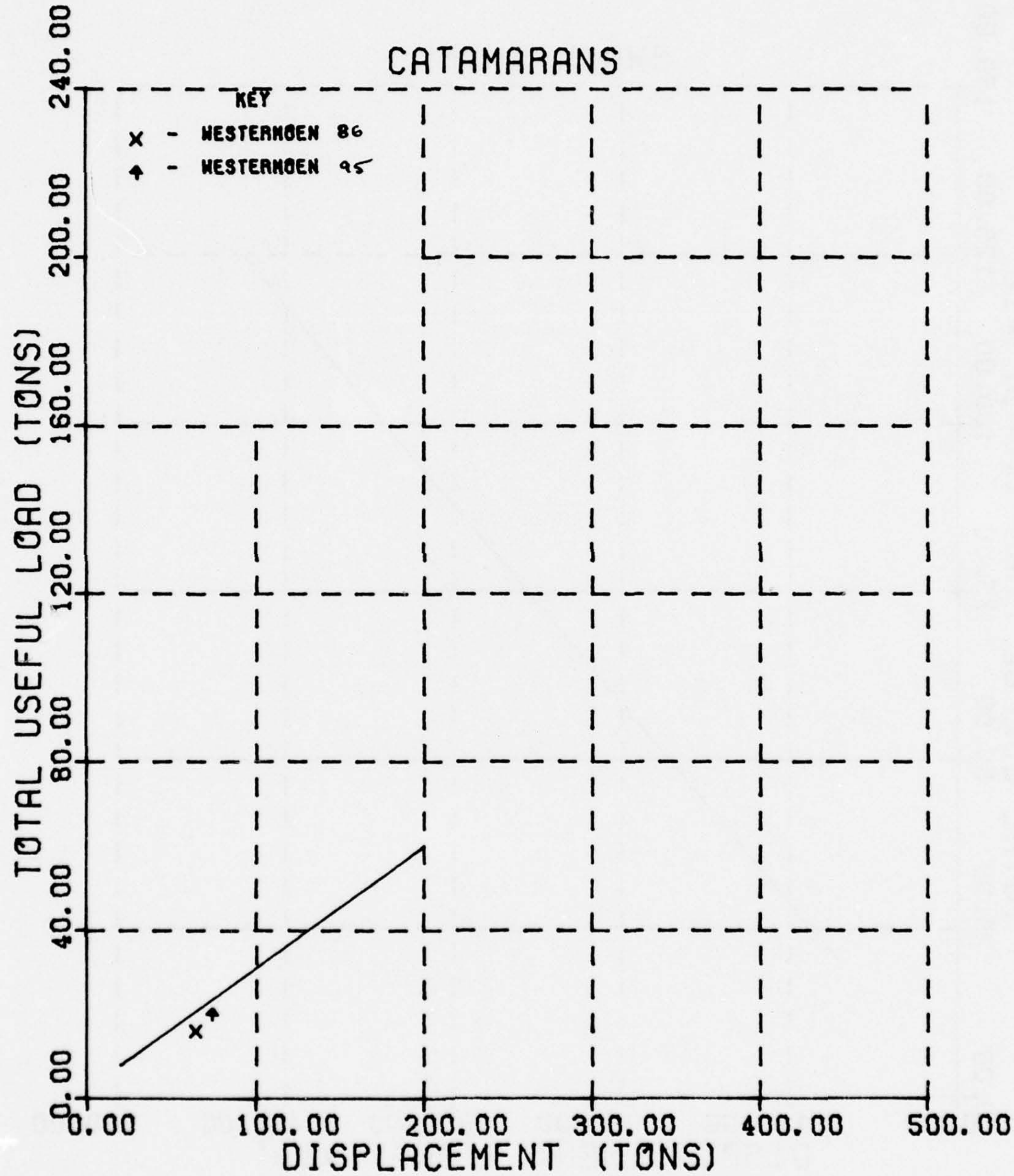

FIGURE A-15

TOTAL USEFUL PAYLOAD
-VS-
DISPLACEMENT

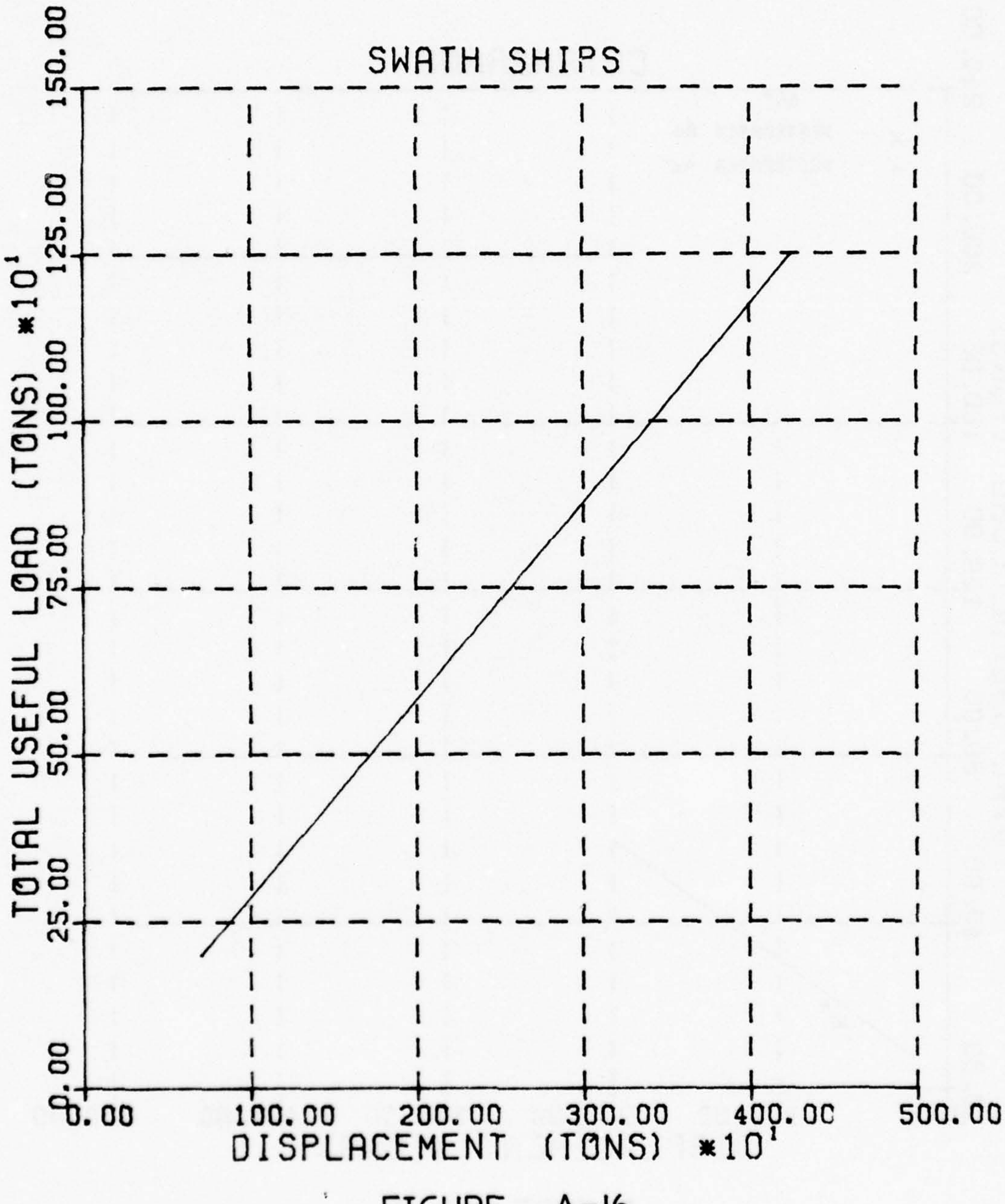

FIGURE A-16

TOTAL USEFUL PAYLOAD
-VS-
DISPLACEMENT

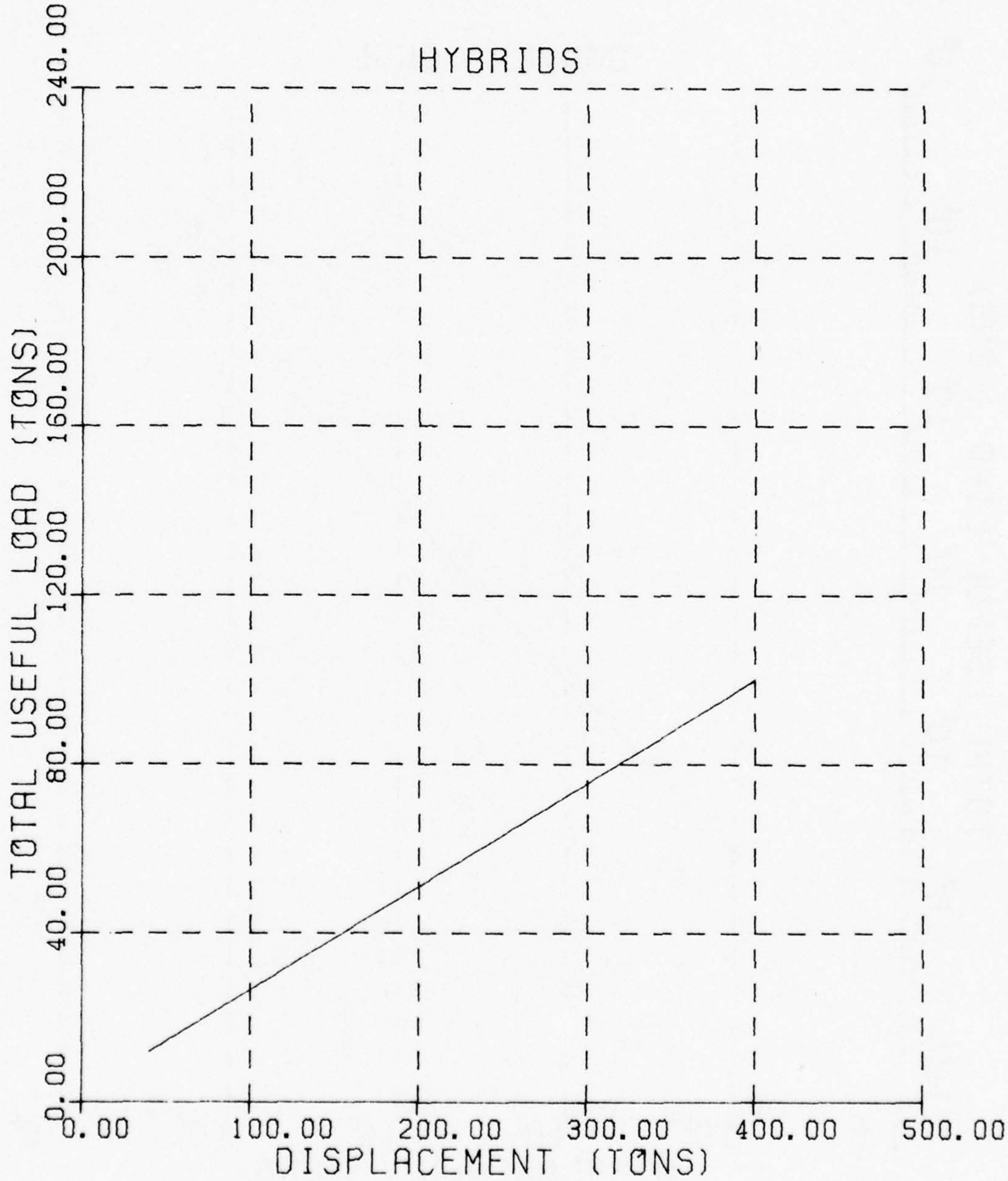

FIGURE A-17

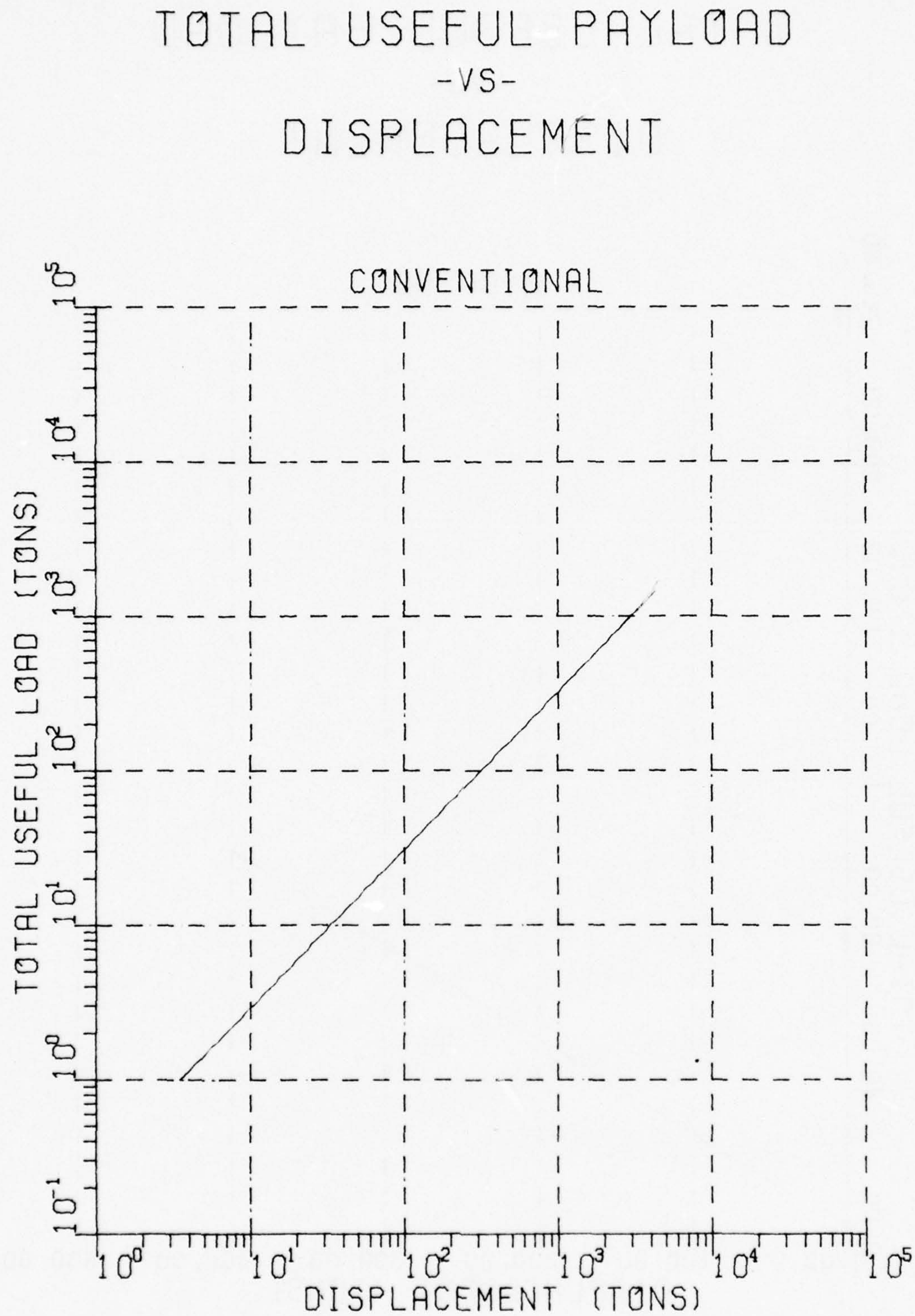
TOTAL USEFUL PAYLOAD
-VS-
DISPLACEMENT
CONVENTIONAL
TOTAL USEFUL LOAD (TONS)
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
DISPLACEMENT (TONS)

FIGURE A-18

INSTALLED HORSEPOWER
-VS-
DISPLACEMENT

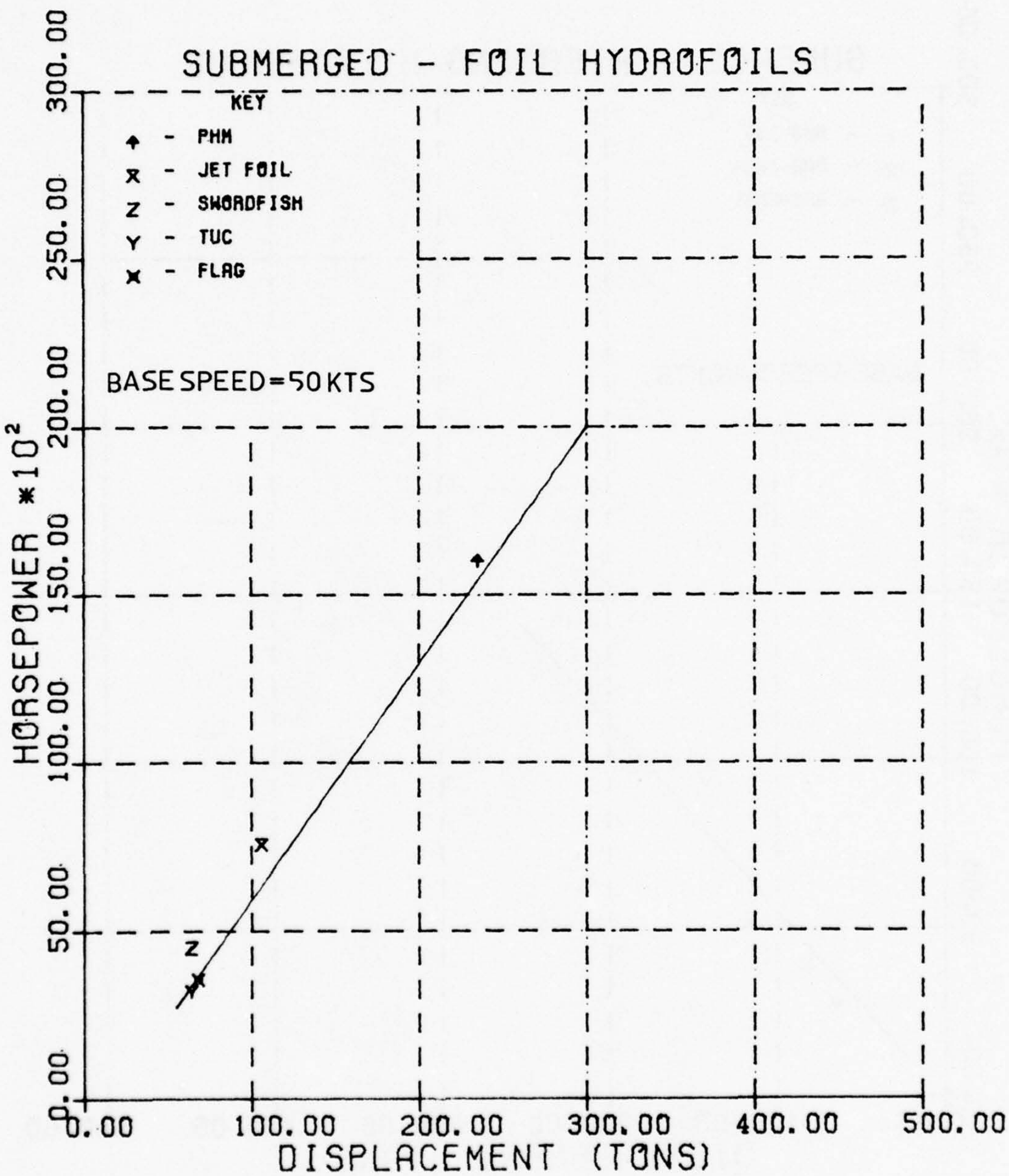

FIGURE A-19

INSTALLED HORSEPOWER
-VS-
DISPLACEMENT

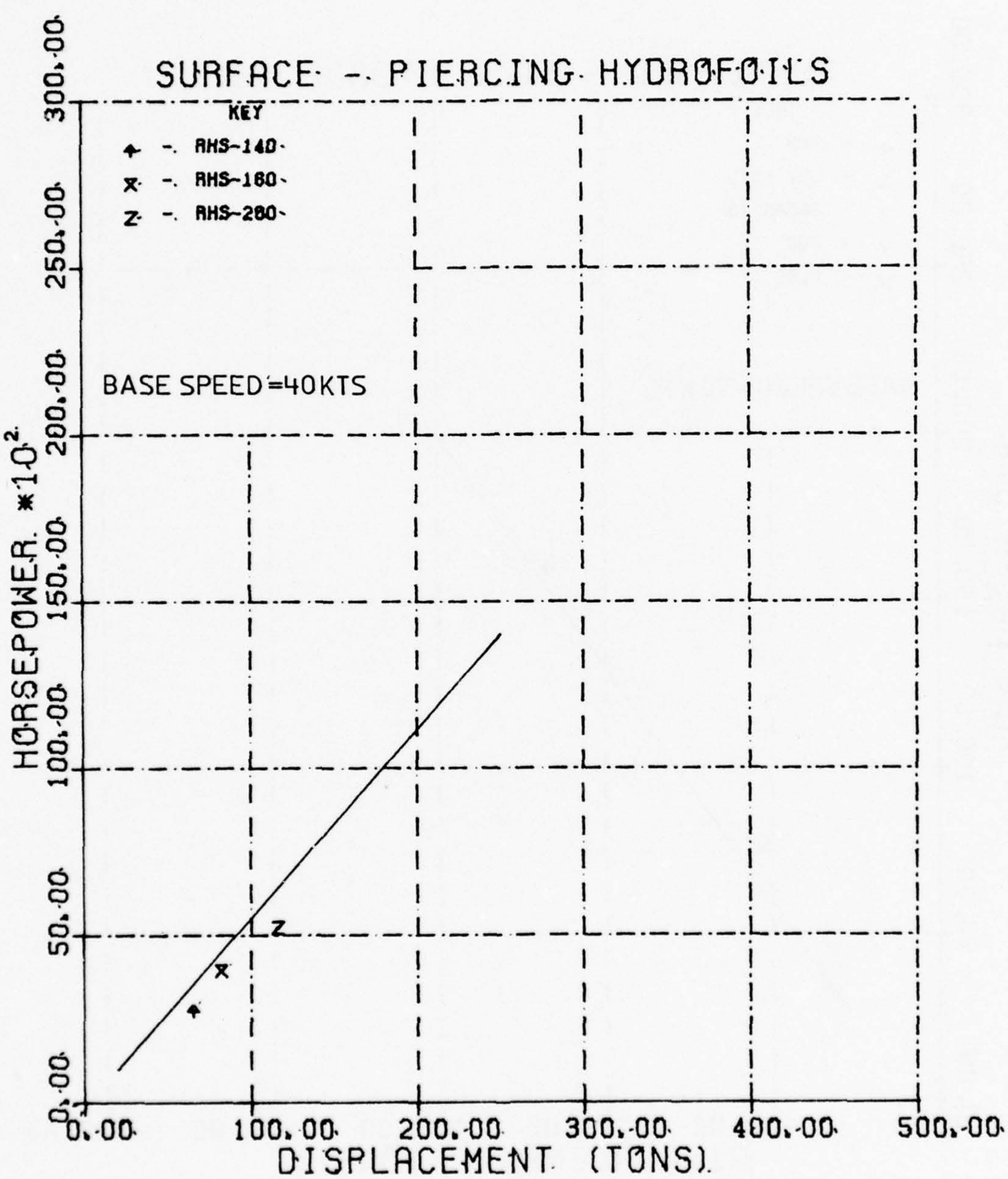

FIGURE A-20

INSTALLED HORSEPOWER
-VS-
DISPLACEMENT

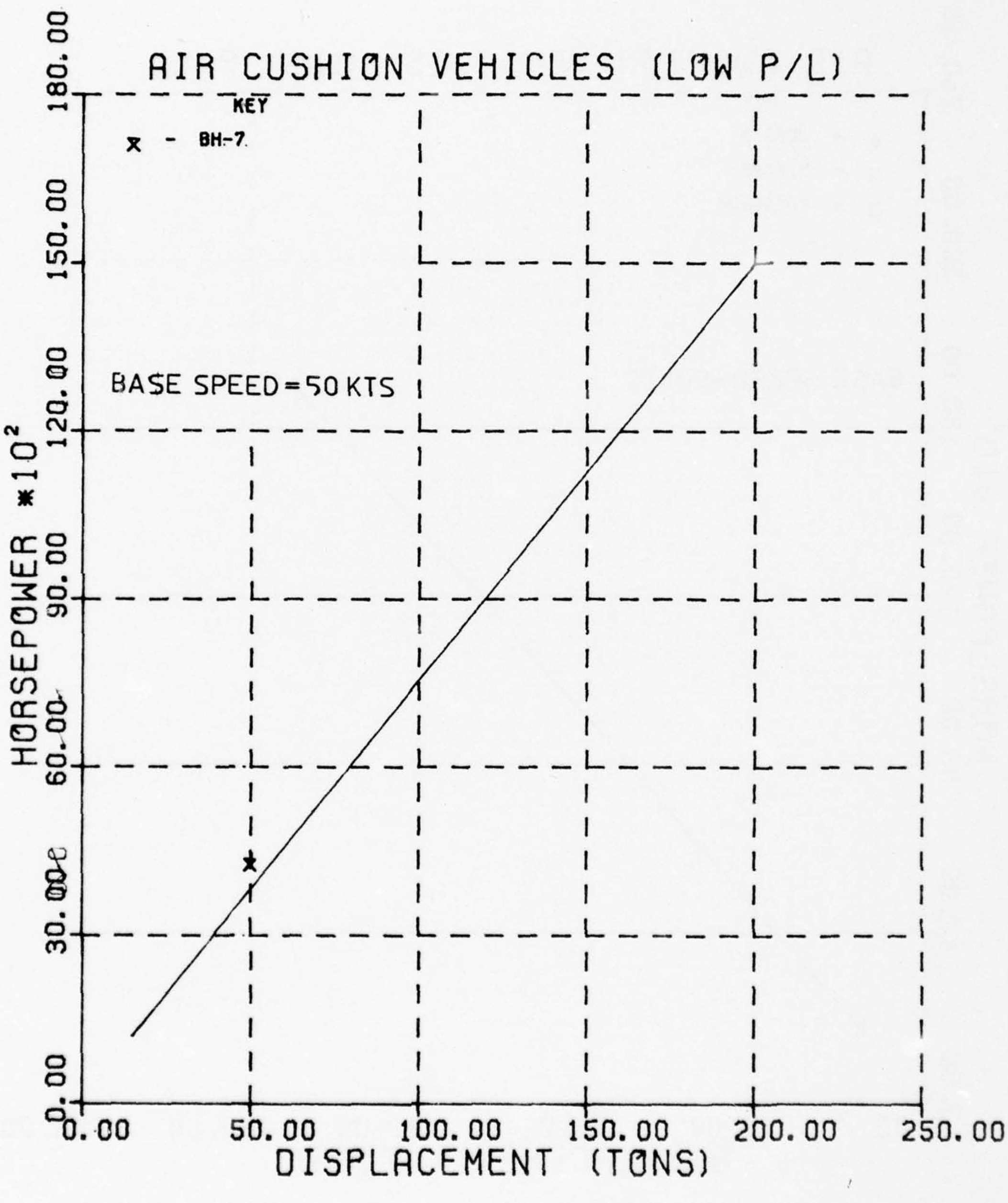

FIGURE A-21

INSTALLED HORSEPOWER
-VS-
DISPLACEMENT

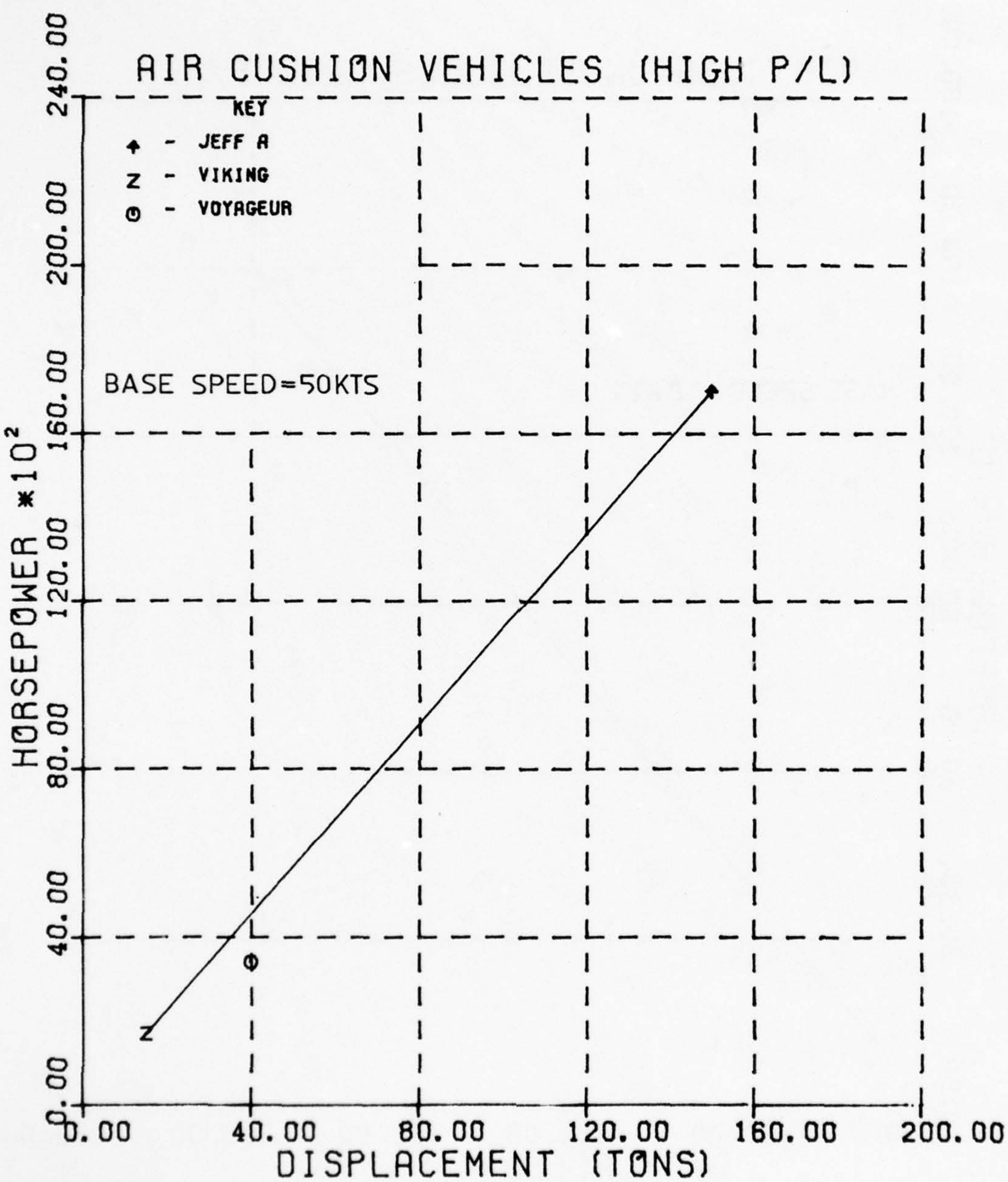

FIGURE A-22

INSTALLED HORSEPOWER
-VS-
DISPLACEMENT

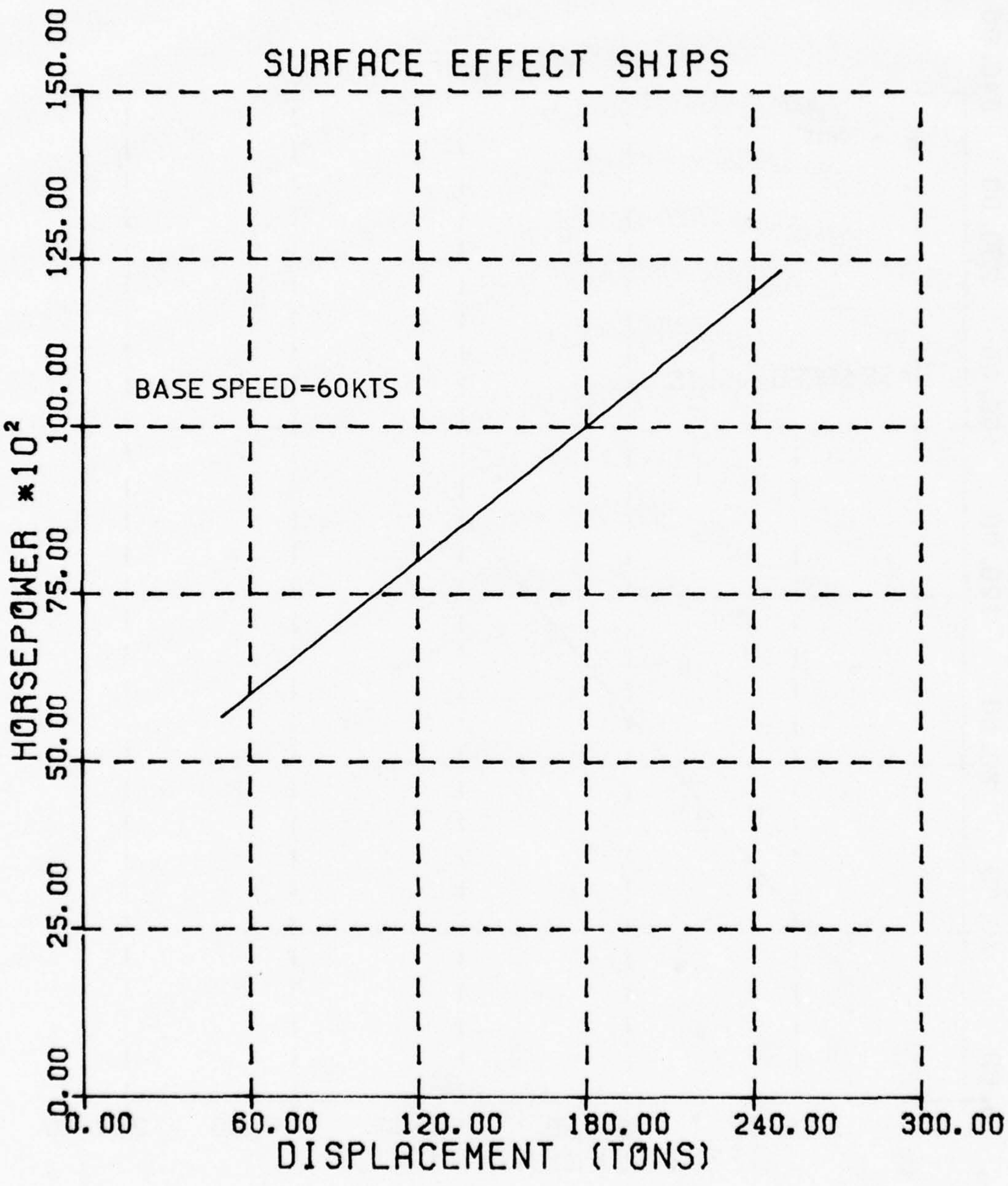

FIGURE A-23

INSTALLED HØRSEPØWER
-VS-
DISPLACEMENT

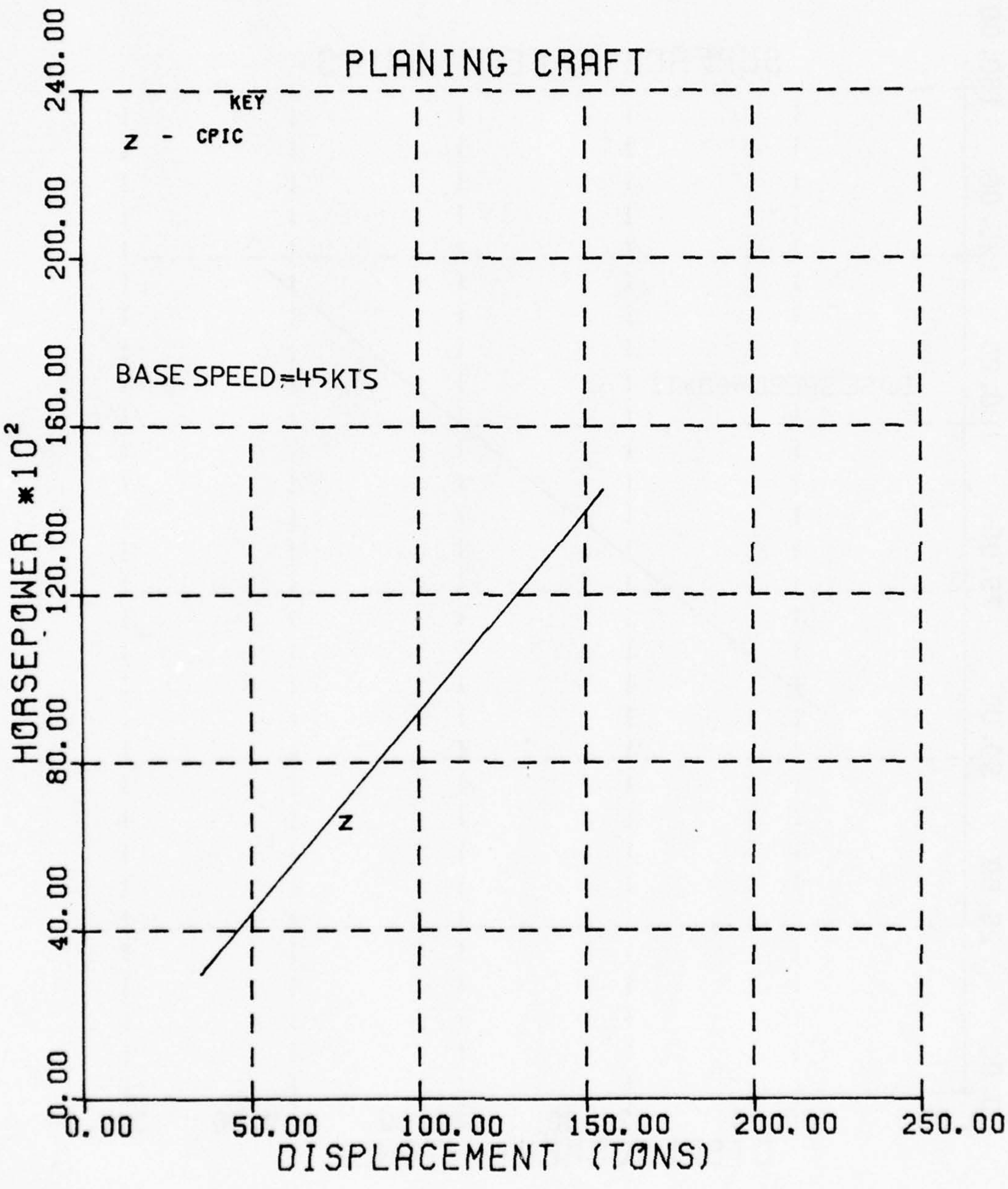

FIGURE A-24

INSTALLED HORSEPOWER
-VS-
DISPLACEMENT

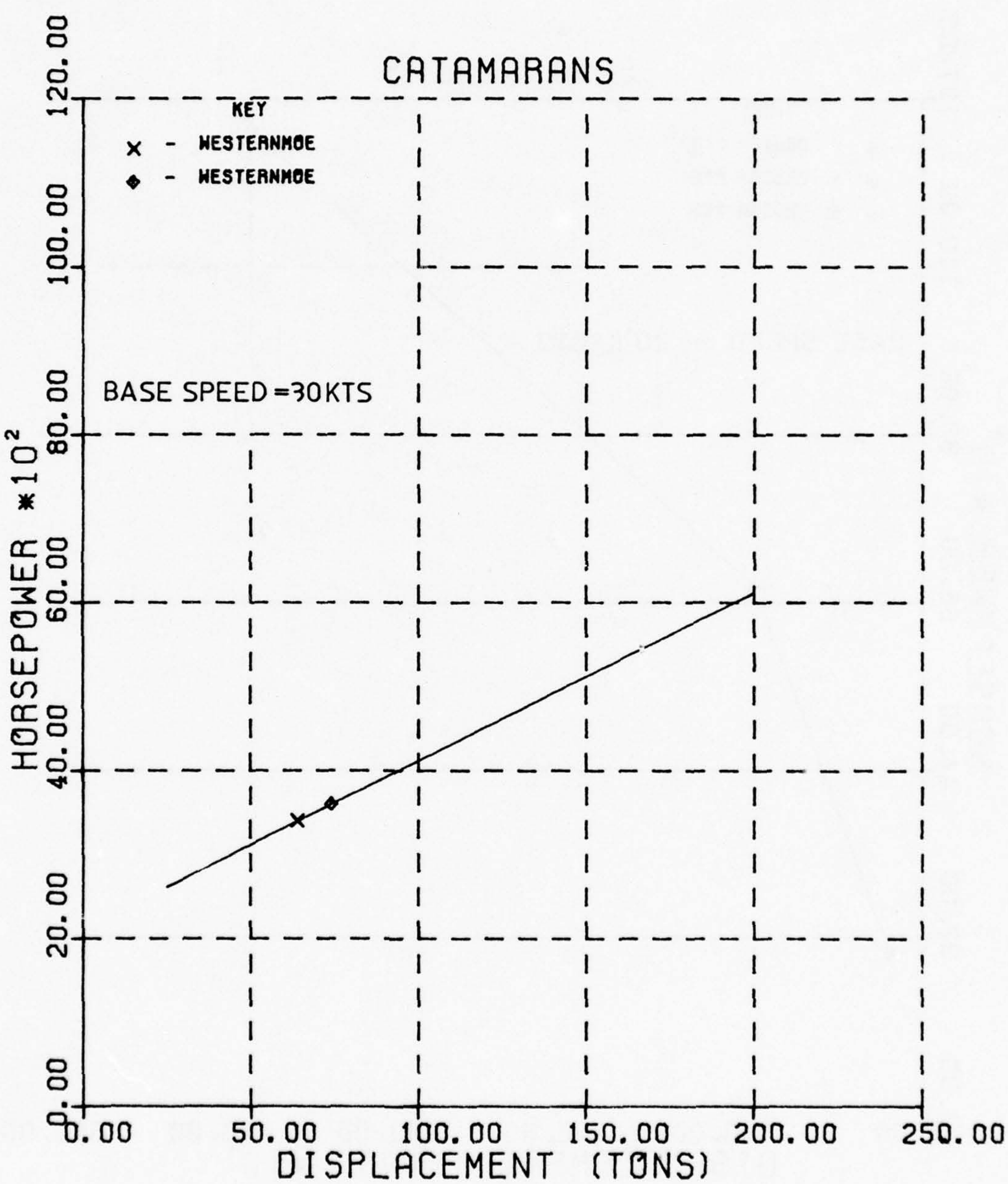

FIGURE A-25

INSTALLED HØRSEPØWER
-VS-
DISPLACEMENT

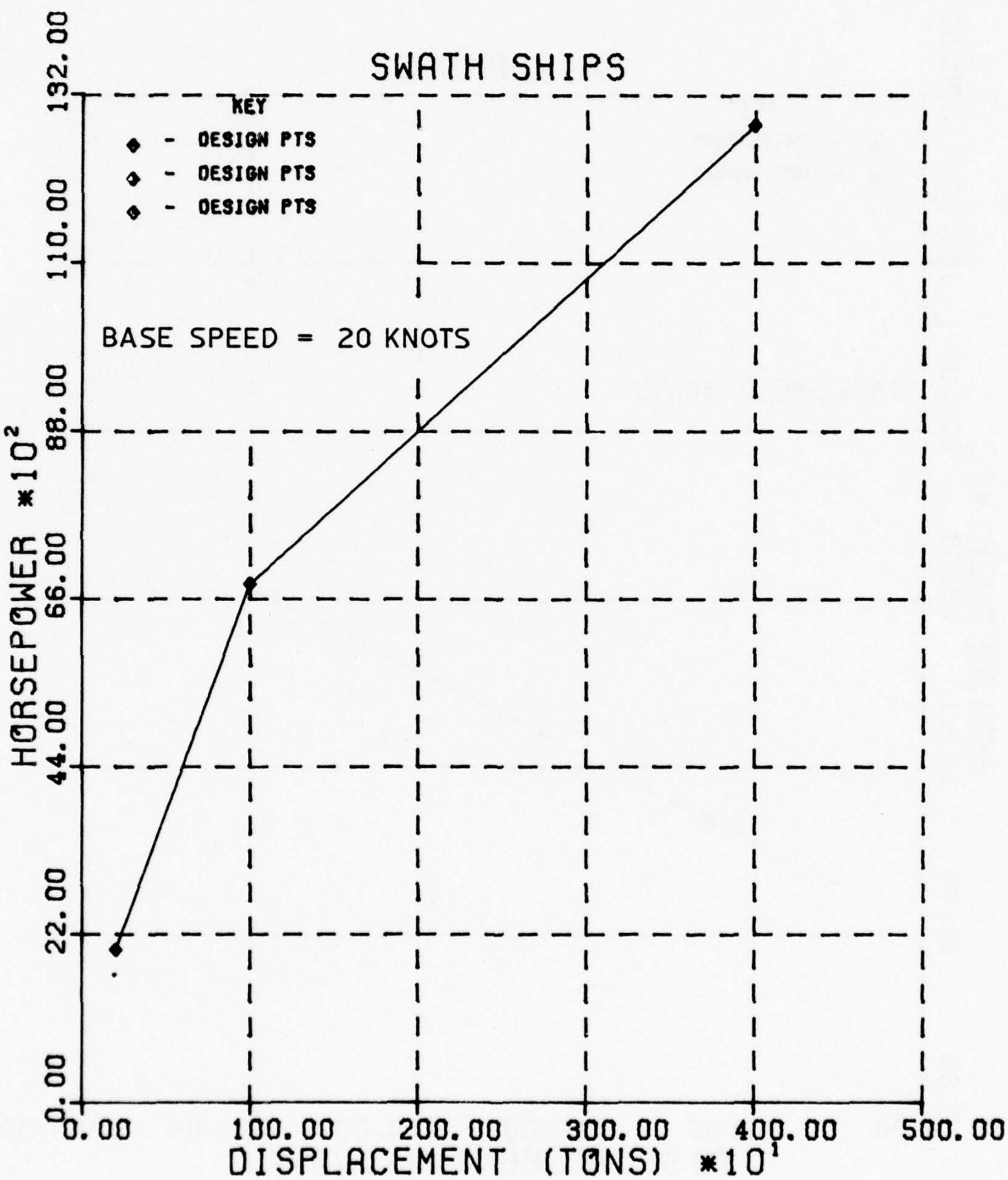

FIGURE A-26

INSTALLED HORSEPOWER
-VS-
DISPLACEMENT

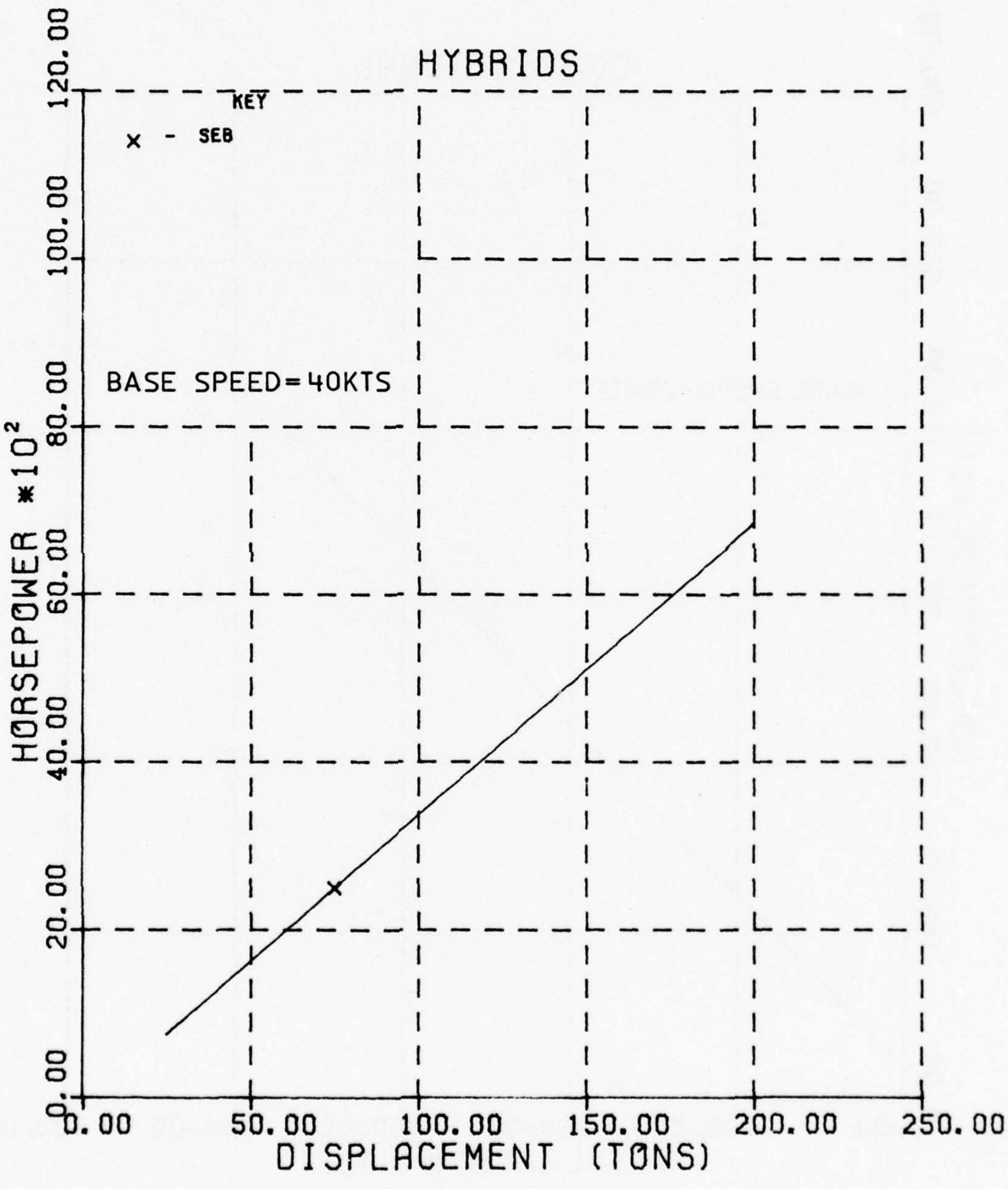

FIGURE A-27

INSTALLED HORSEPOWER
-VS-
DISPLACEMENT

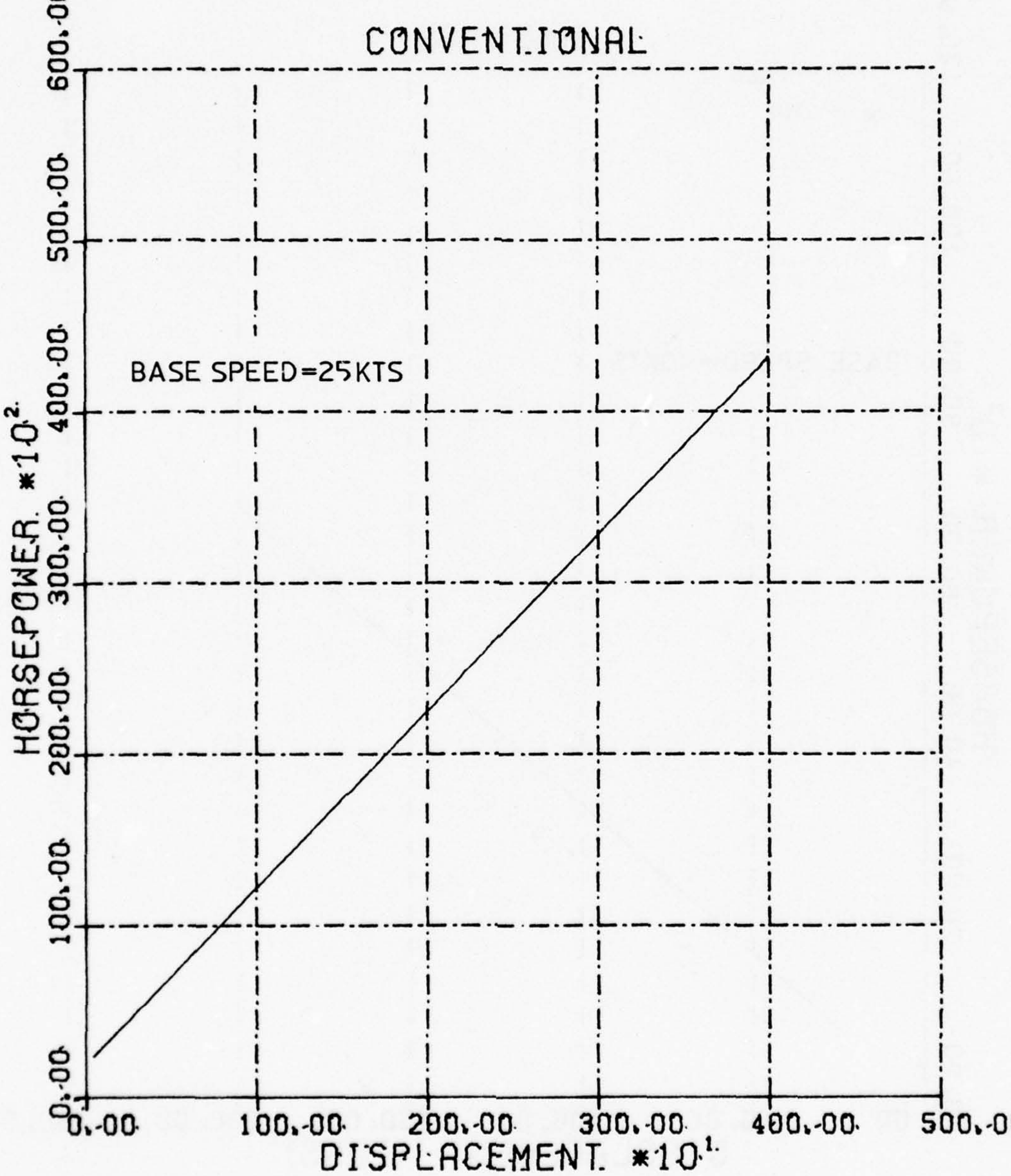

FIGURE A-28

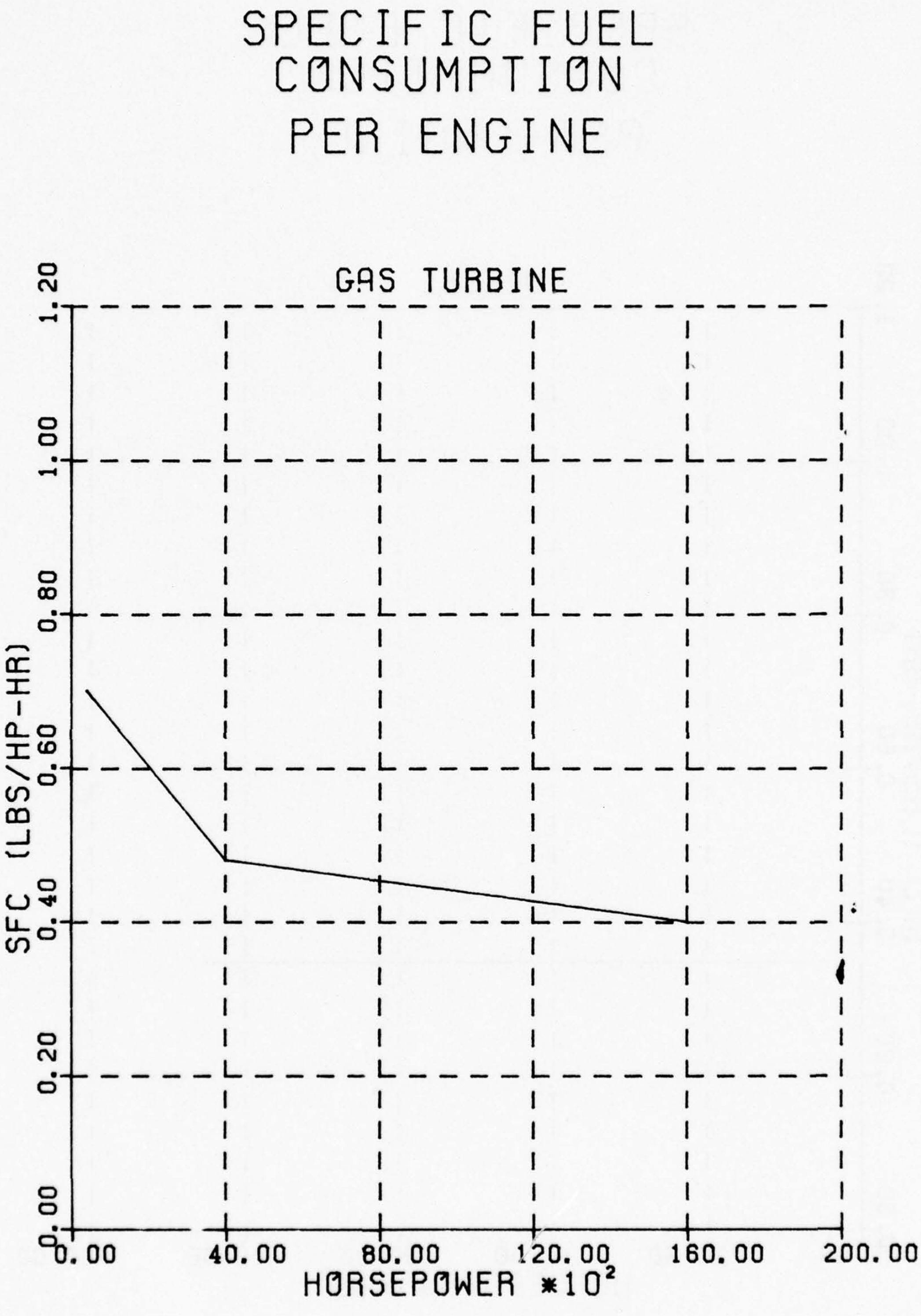
SPECIFIC FUEL
CONSUMPTION
PER ENGINE
GAS TURBINE
SFC (LBS/HP-HR)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
0.00
40.00
80.00
120.00
160.00
200.00
HORSEPOWER *10²

FIGURE A-29

SPECIFIC FUEL CONSUMPTION PER ENGINE

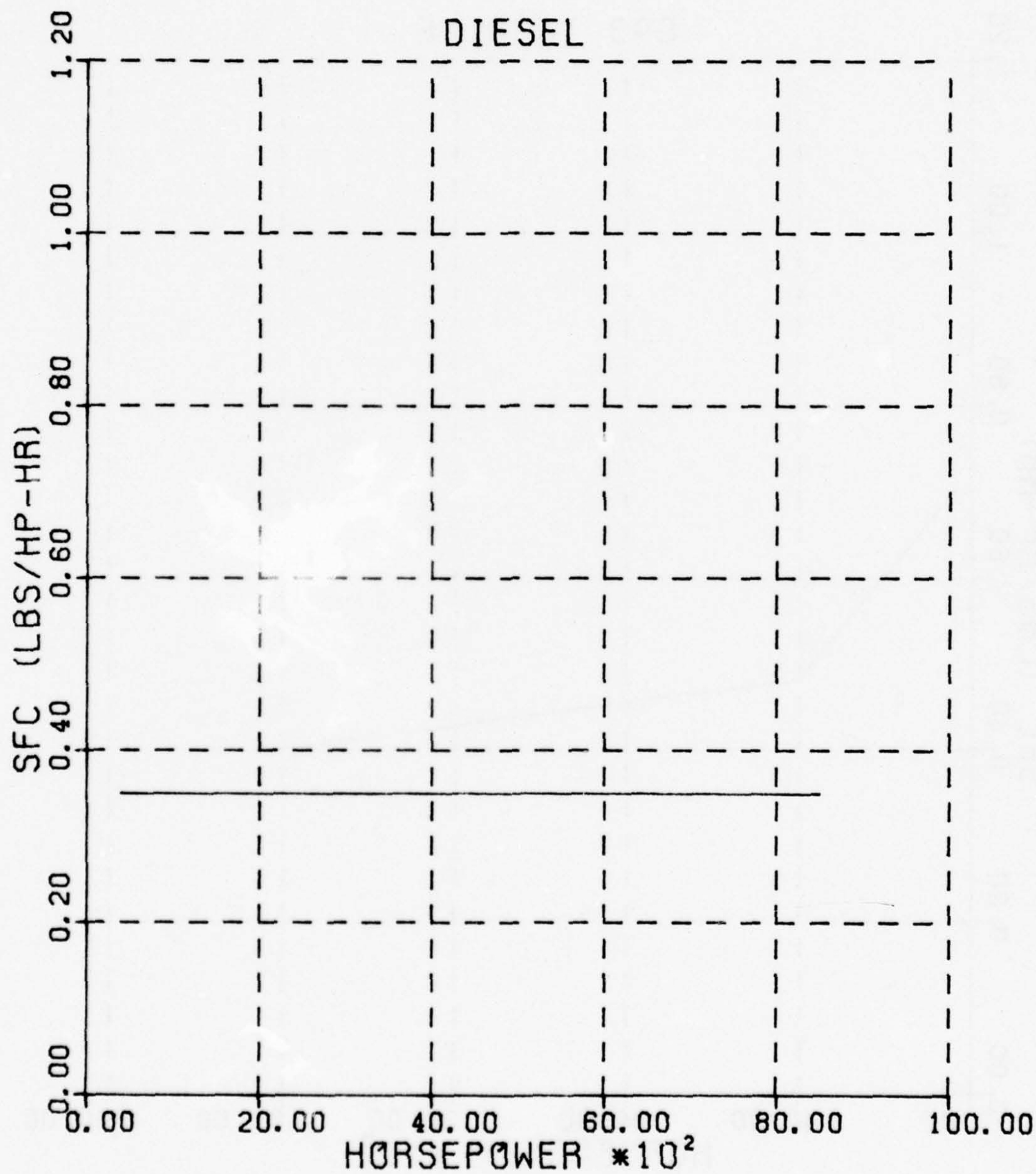

FIGURE A-30

SFC-CORRECTION FACTOR

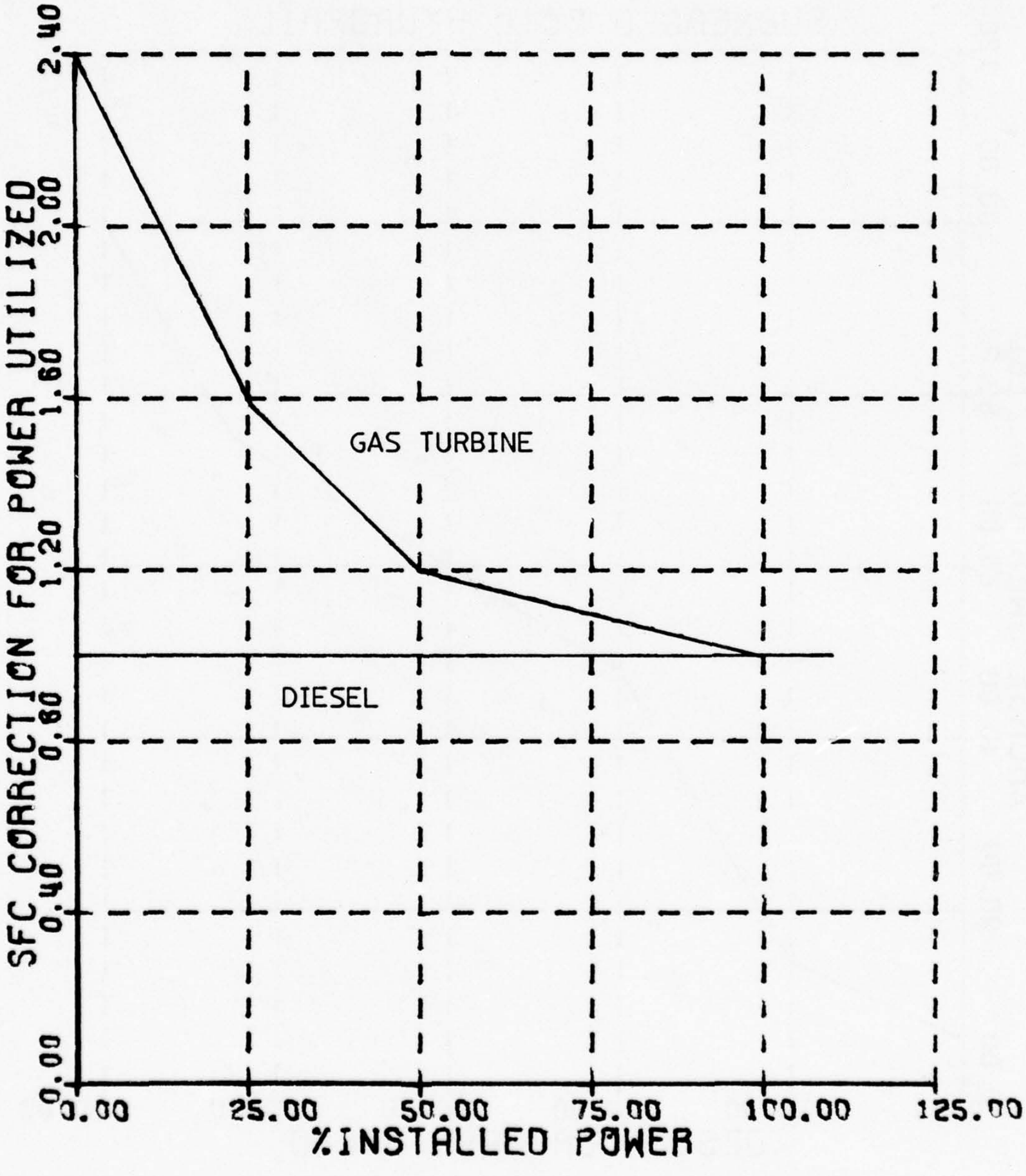

FIGURE A-31

%HORSEPOWER UTILIZED
-VS-
%DESIGN OR BASE SPEED

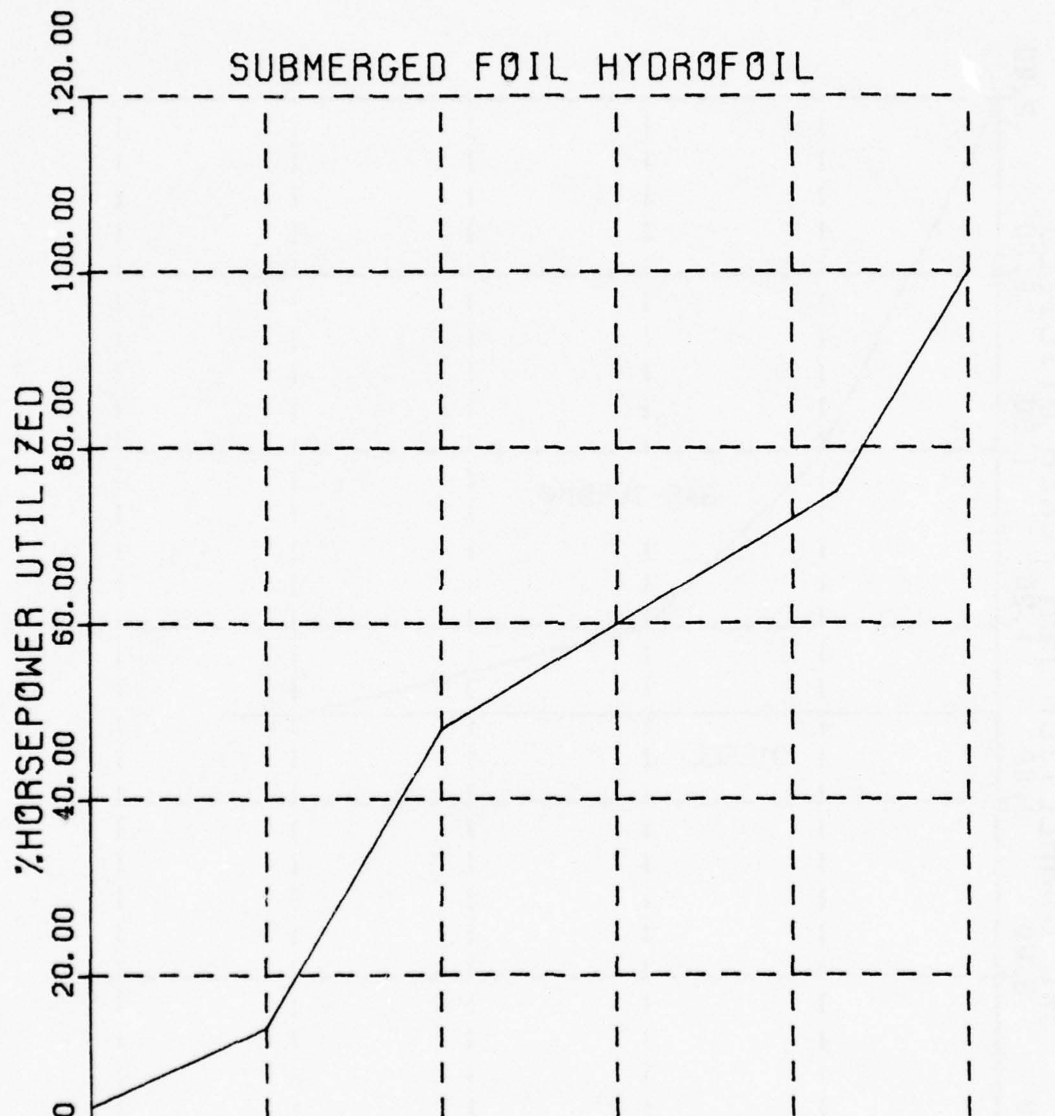

FIGURE A-32

%HORSEPOWER UTILIZED
-VS-
%DESIGN OR BASE SPEED

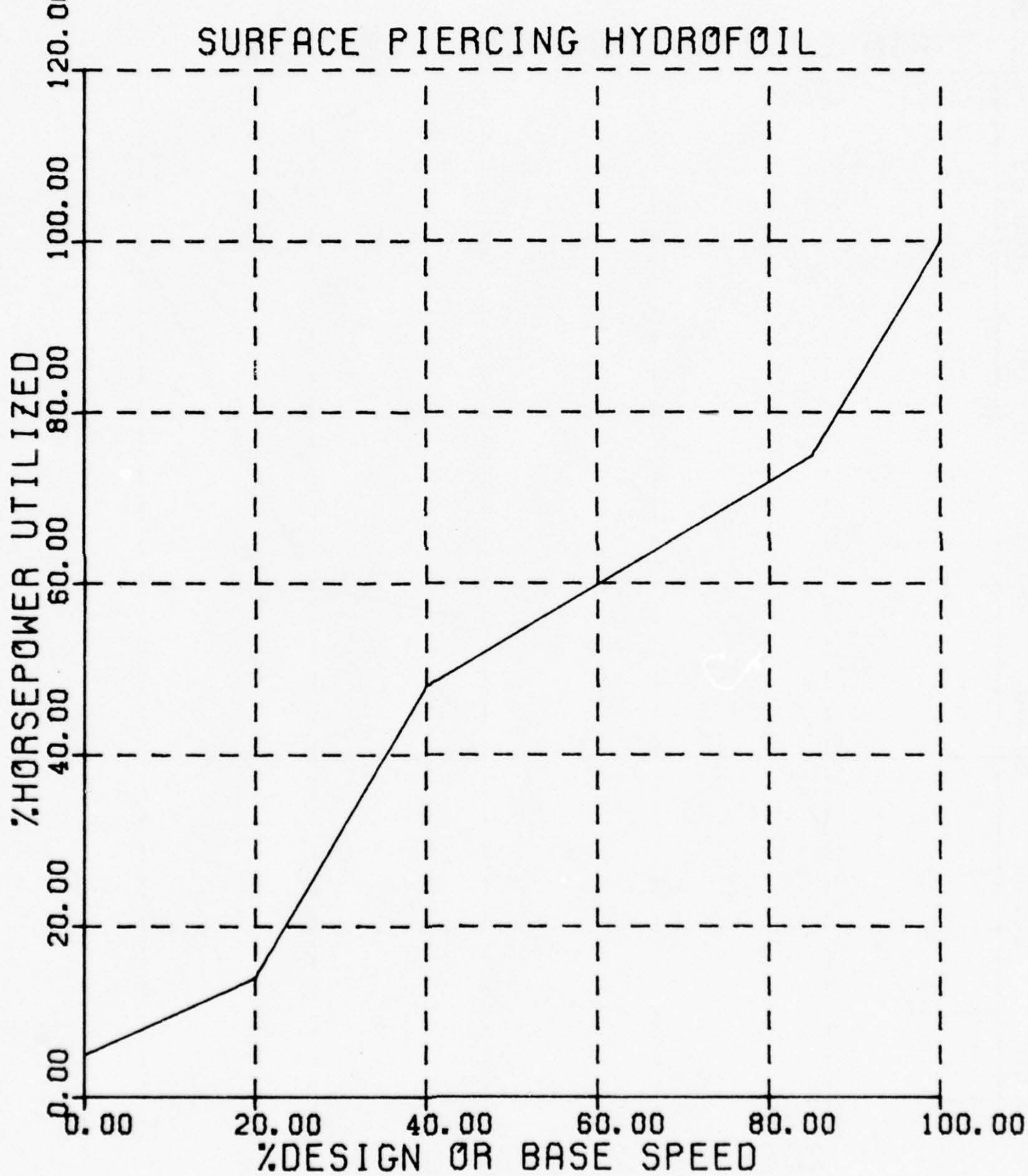

FIGURE A-33

%HORSEPOWER UTILIZED
-VS-
%DESIGN OR BASE SPEED

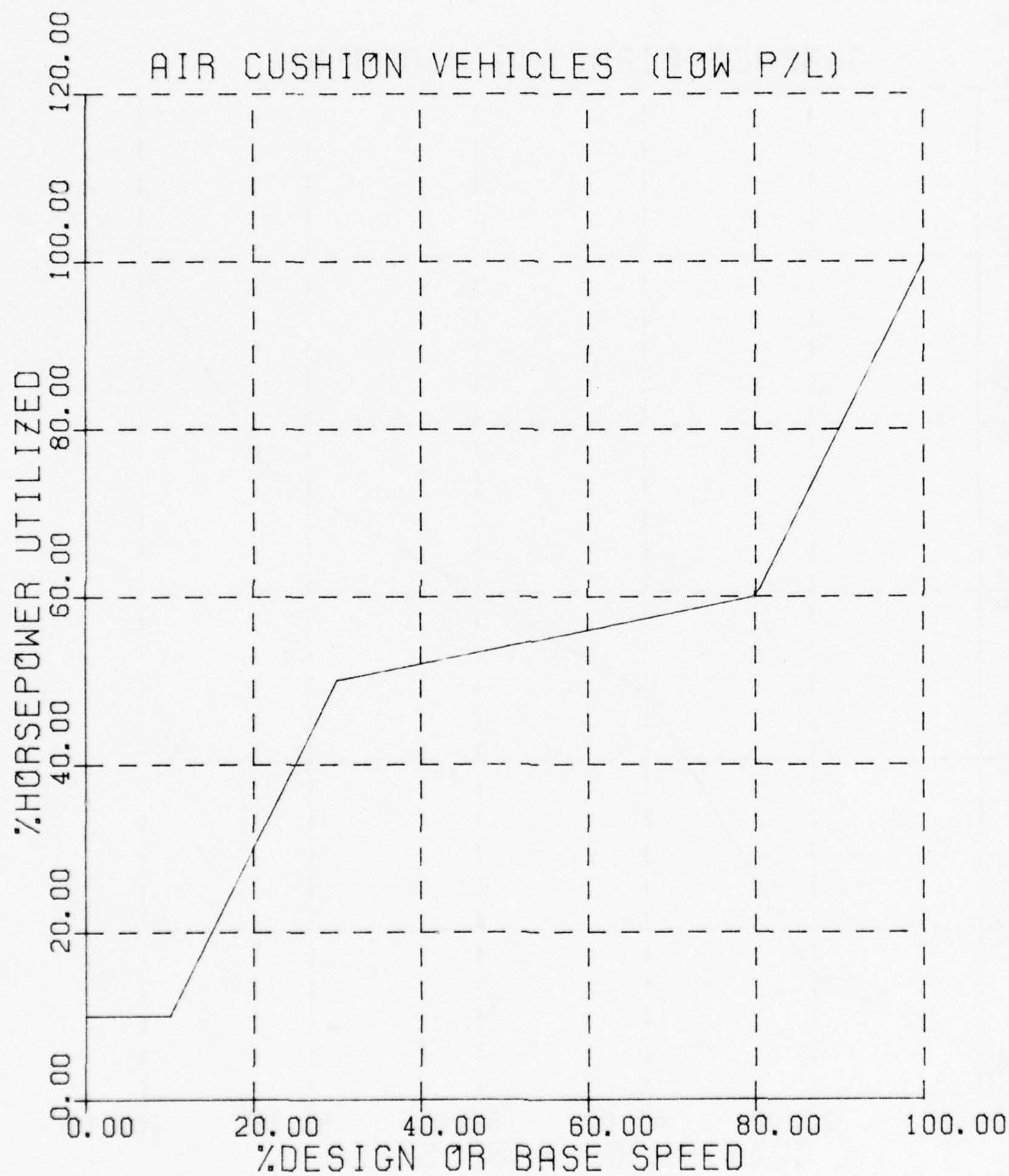

FIGURE A-34

%HORSEPOWER UTILIZED
-VS-
%DESIGN OR BASE SPEED

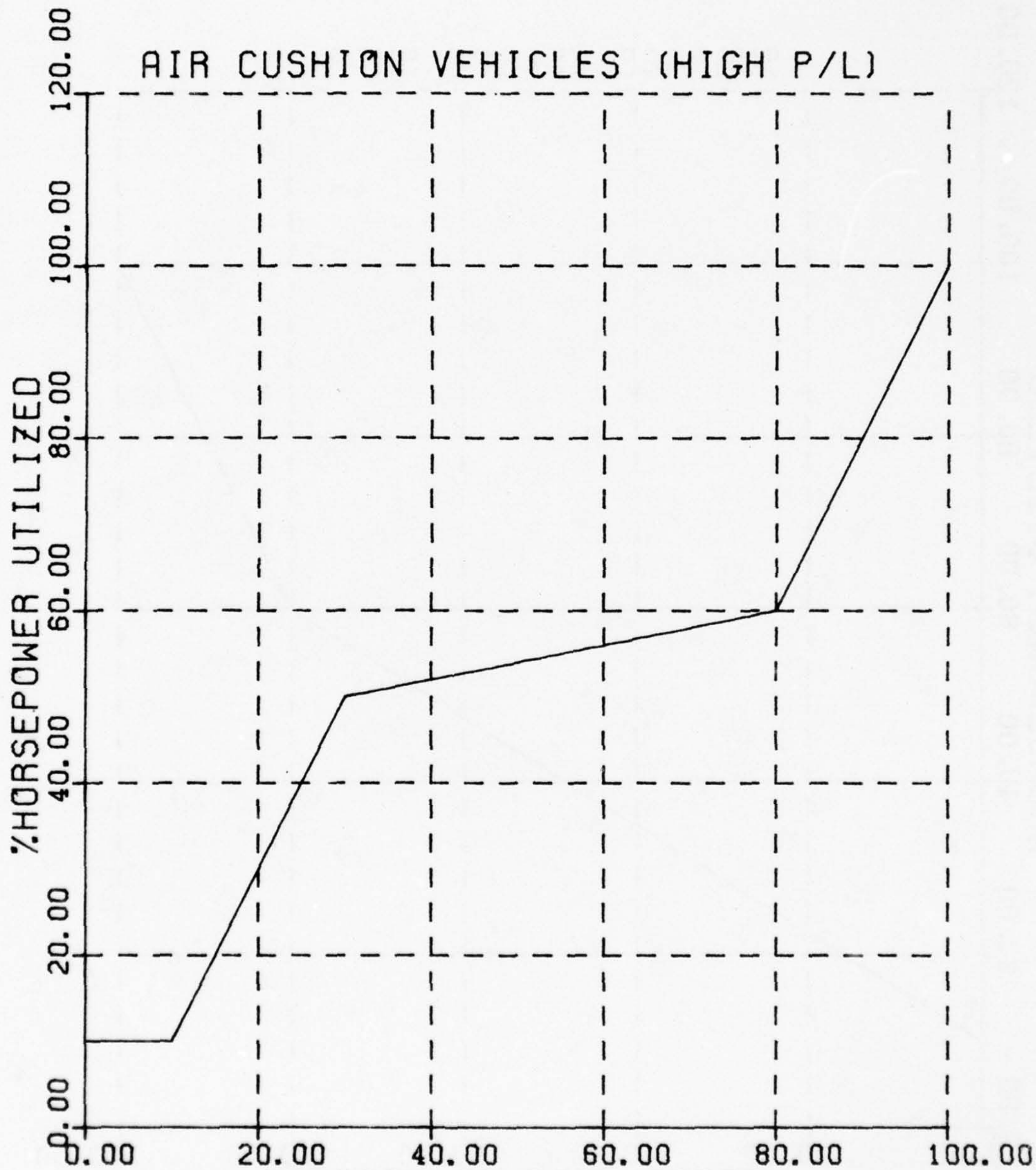

FIGURE A-35

%HORSEPOWER UTILIZED
-VS-
%DESIGN OR BASE SPEED

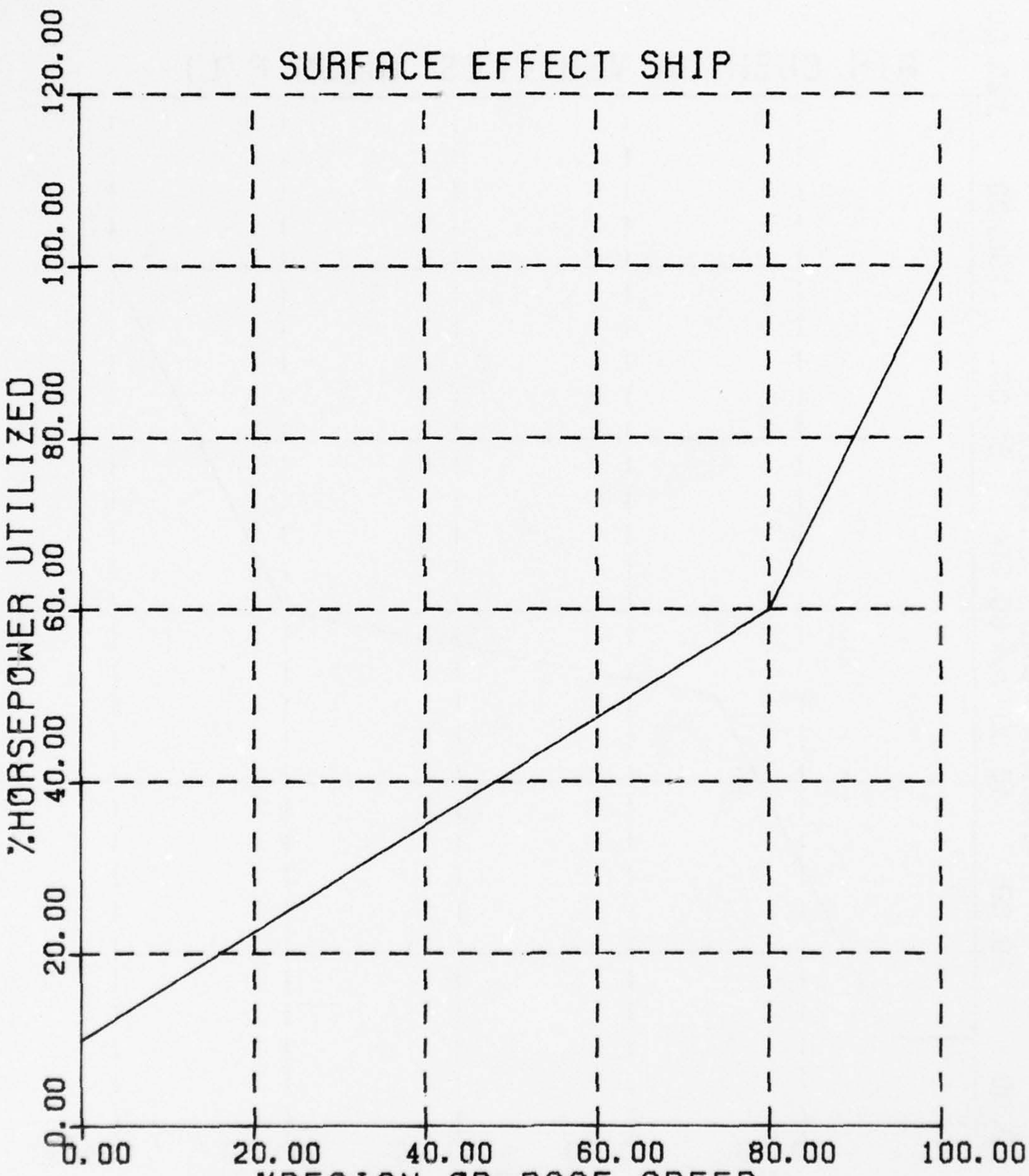

FIGURE A-36

%HORSEPOWER UTILIZED
-VS-
%DESIGN OR BASE SPEED

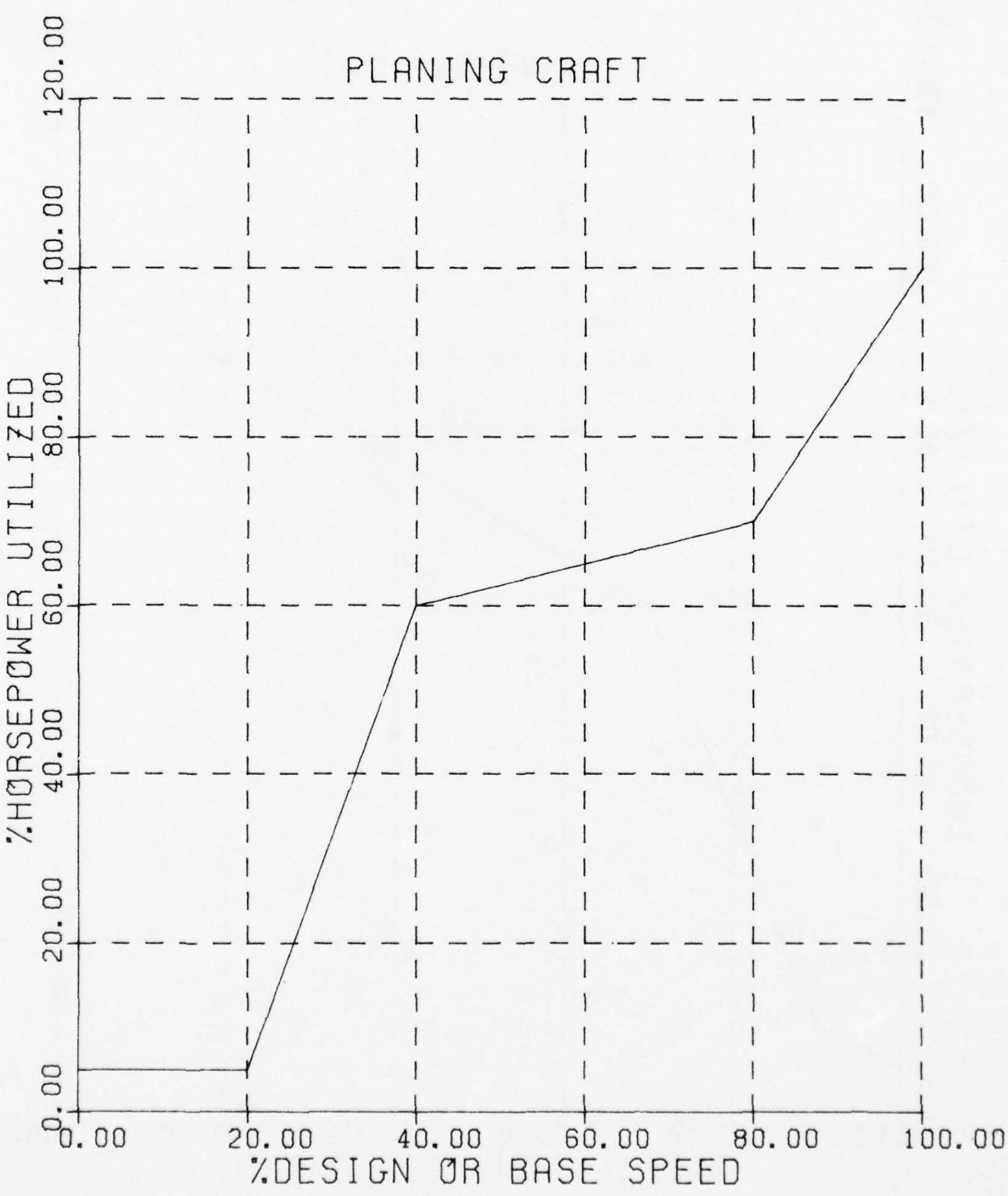

FIGURE A-37

%HORSEPOWER UTILIZED
-VS-
%DESIGN OR BASE SPEED

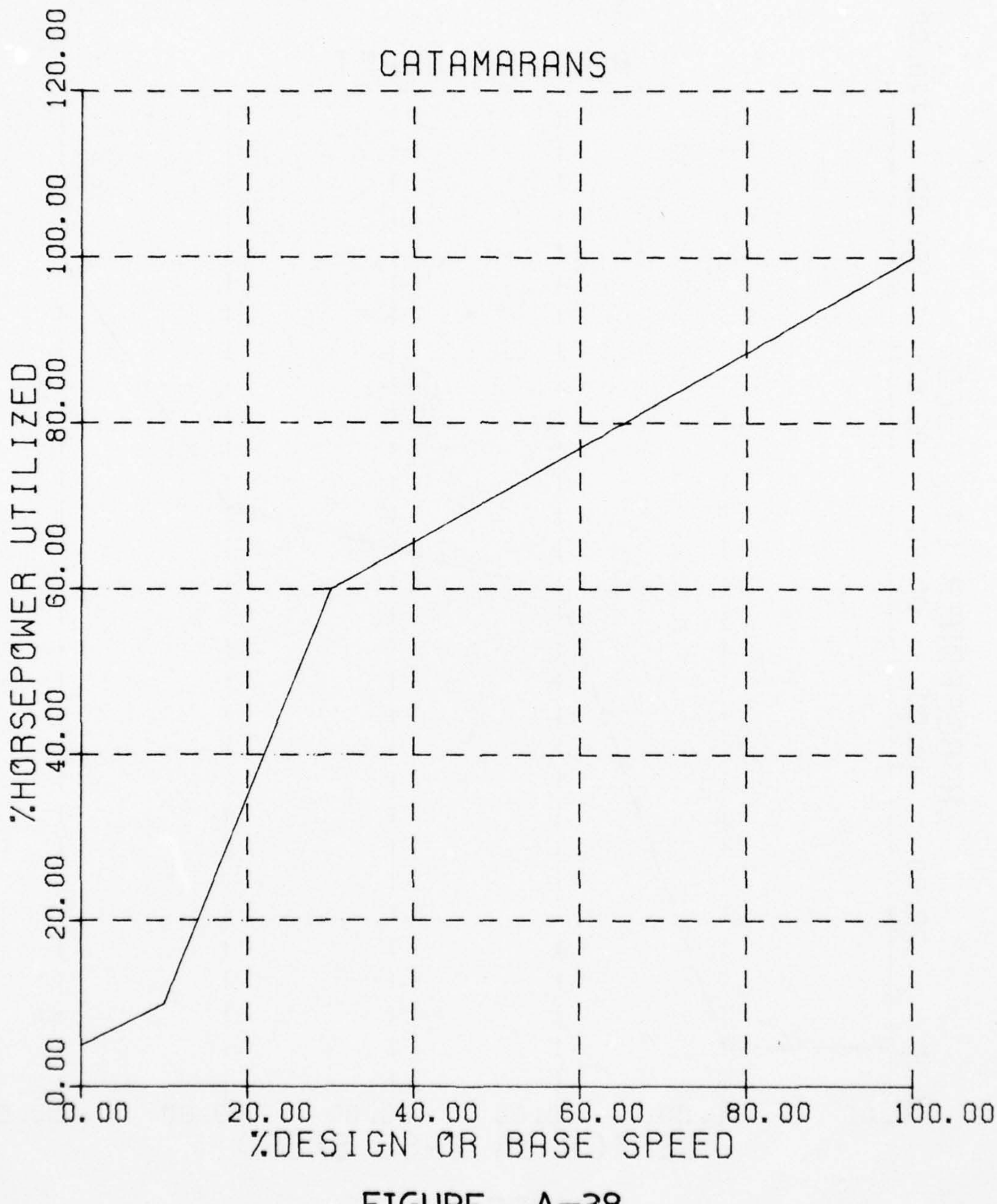

FIGURE A-38

%HORSEPOWER UTILIZED
-VS-
%DESIGN OR BASE SPEED

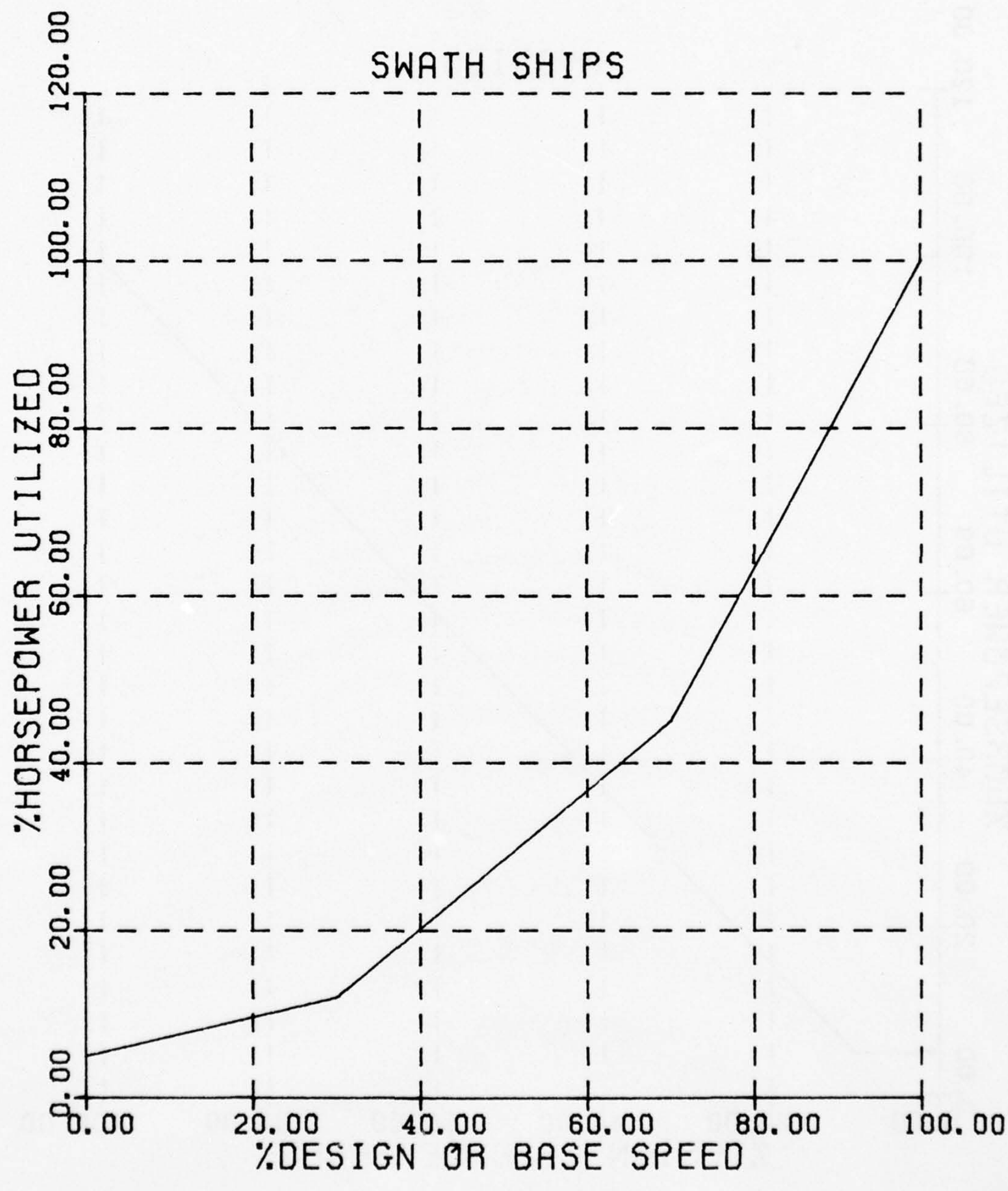

FIGURE A-39

%HORSEPOWER UTILIZED
-VS-
%DESIGN OR BASE SPEED

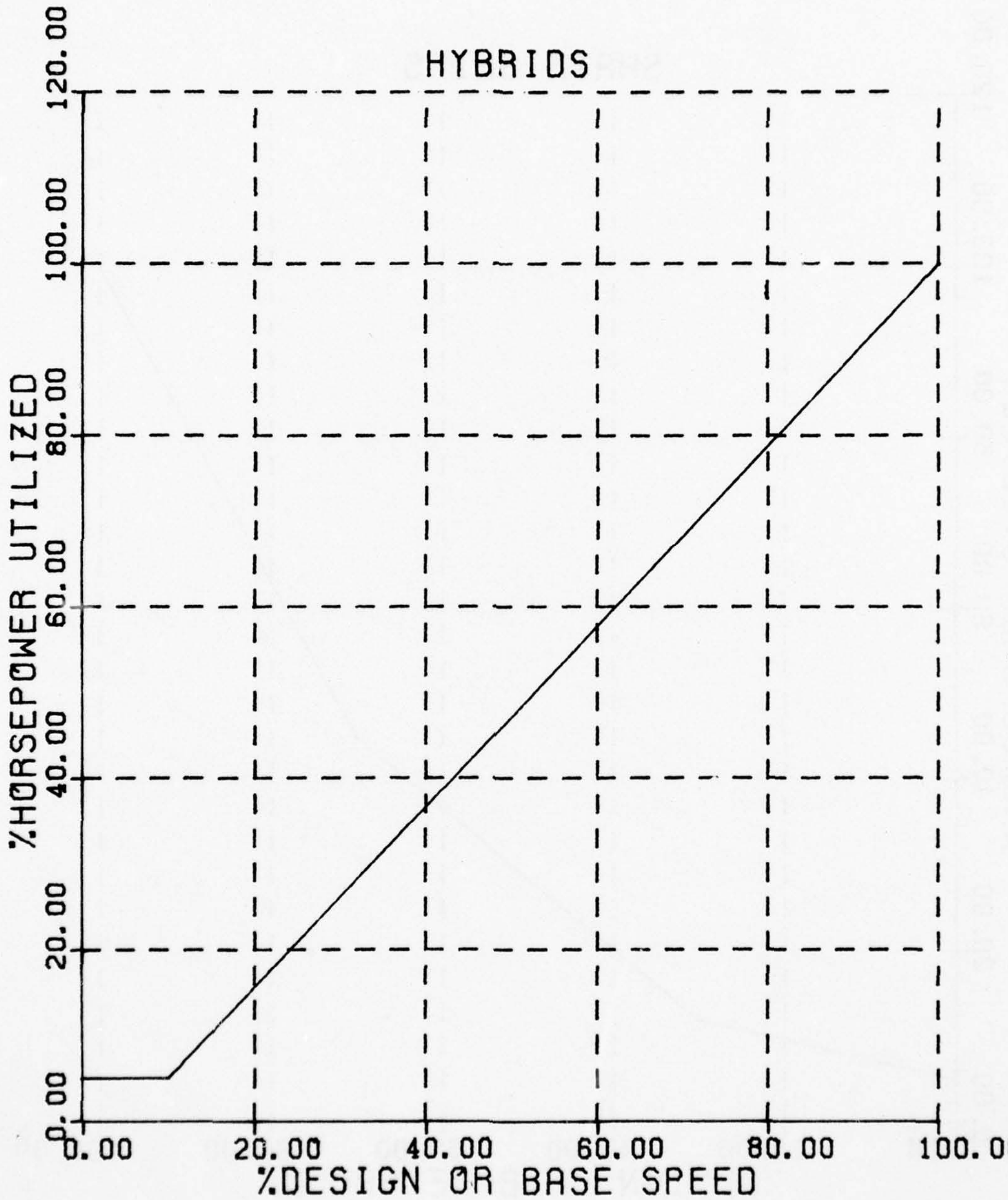

FIGURE A-40

%HORSEPOWER UTILIZED
-VS-
%DESIGN OR BASE SPEED

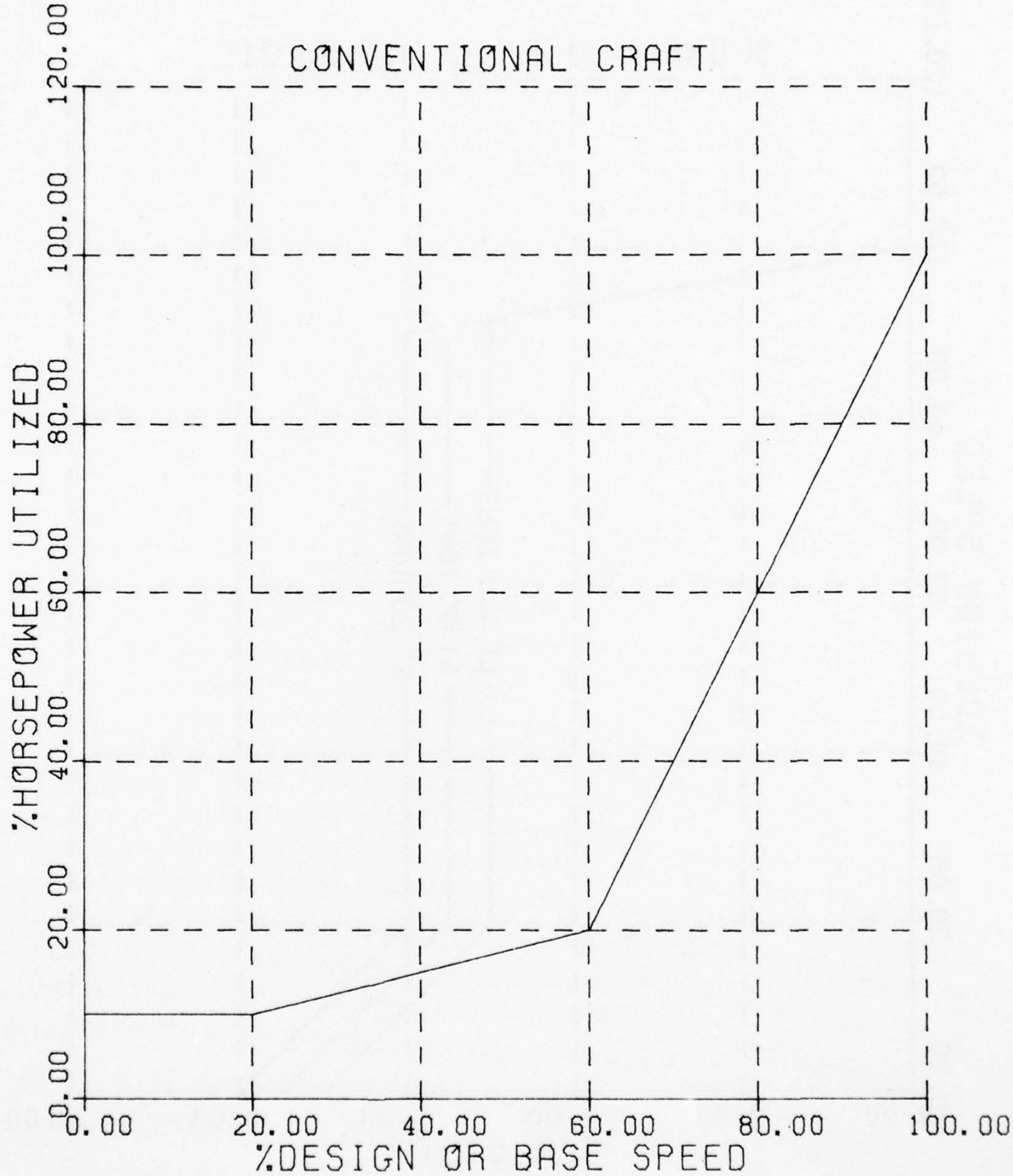

FIGURE A-41

SPEED - SEA STATE ENVELOPE

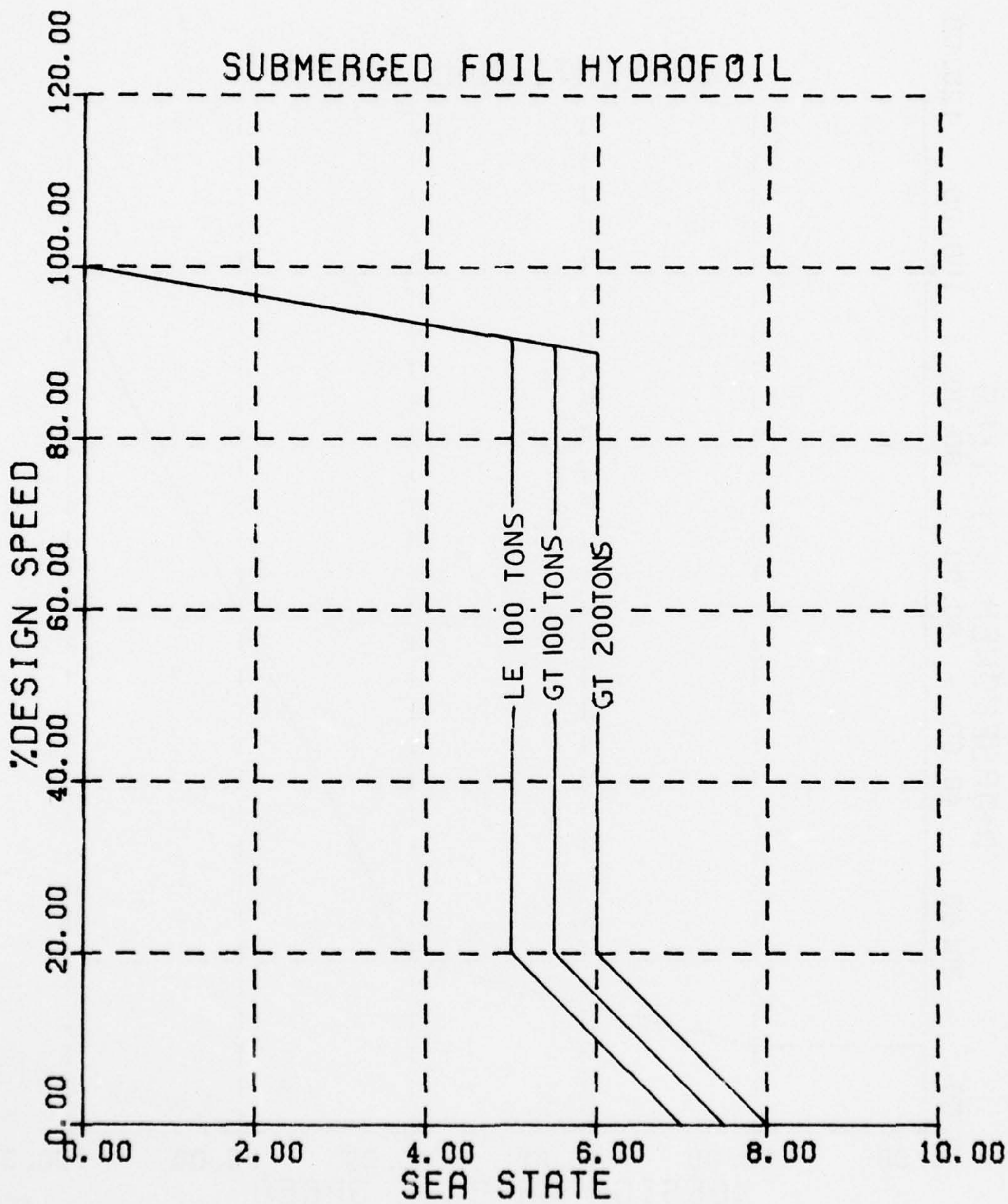

FIGURE A-42

SPEED - SEA STATE ENVELOPE

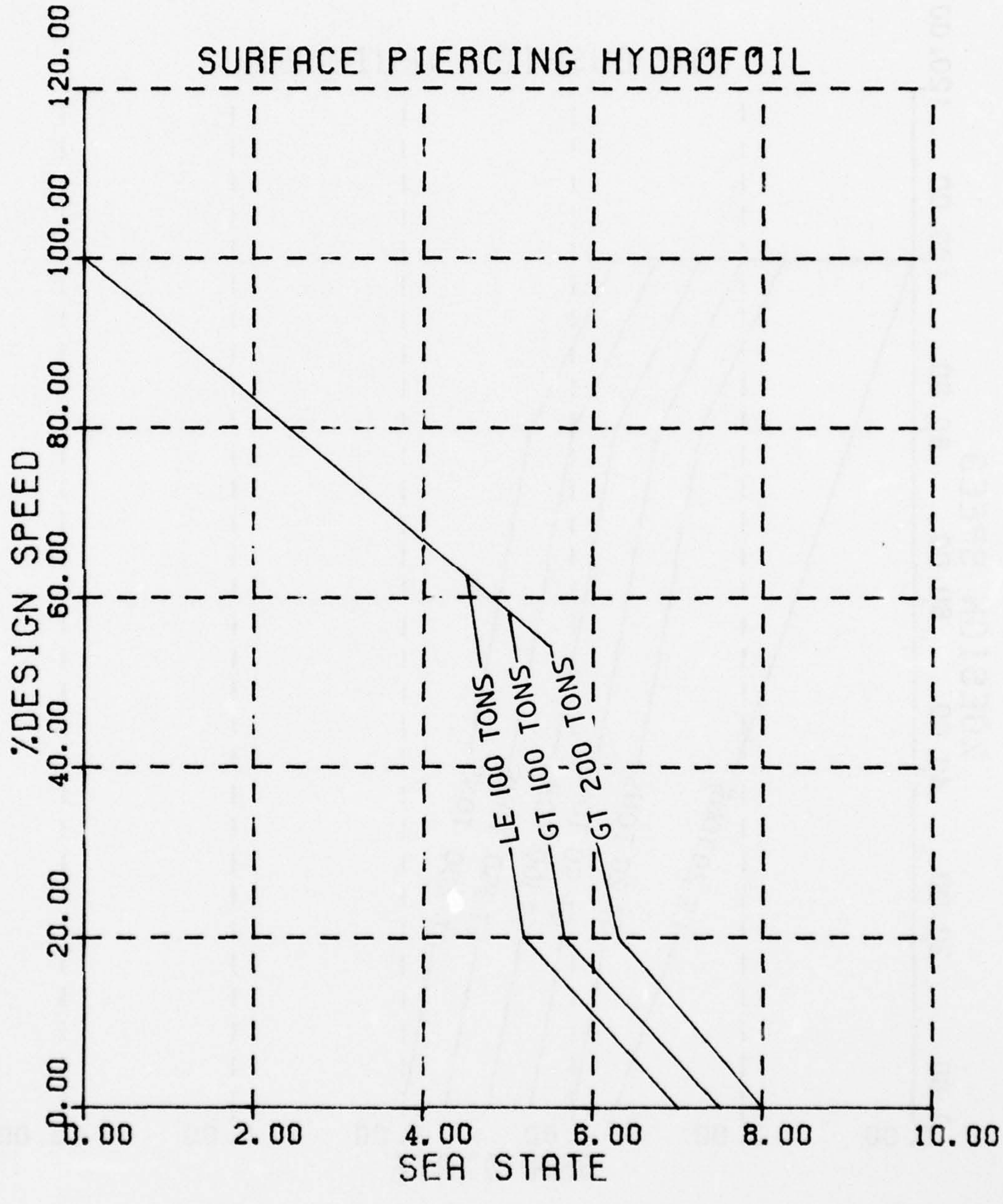

FIGURE A-43

SPEED - SEA STATE ENVELOPE

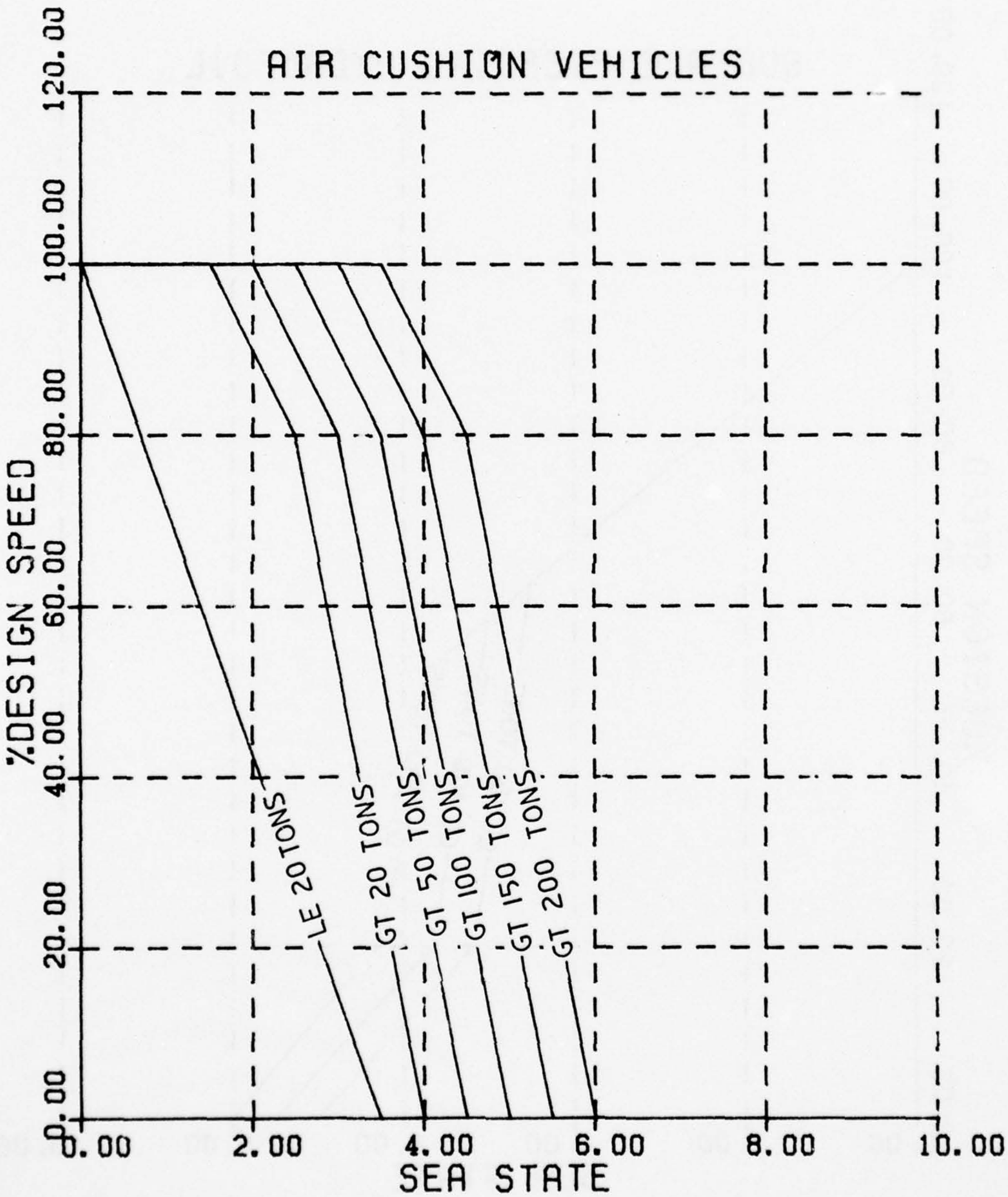

FIGURE A-44

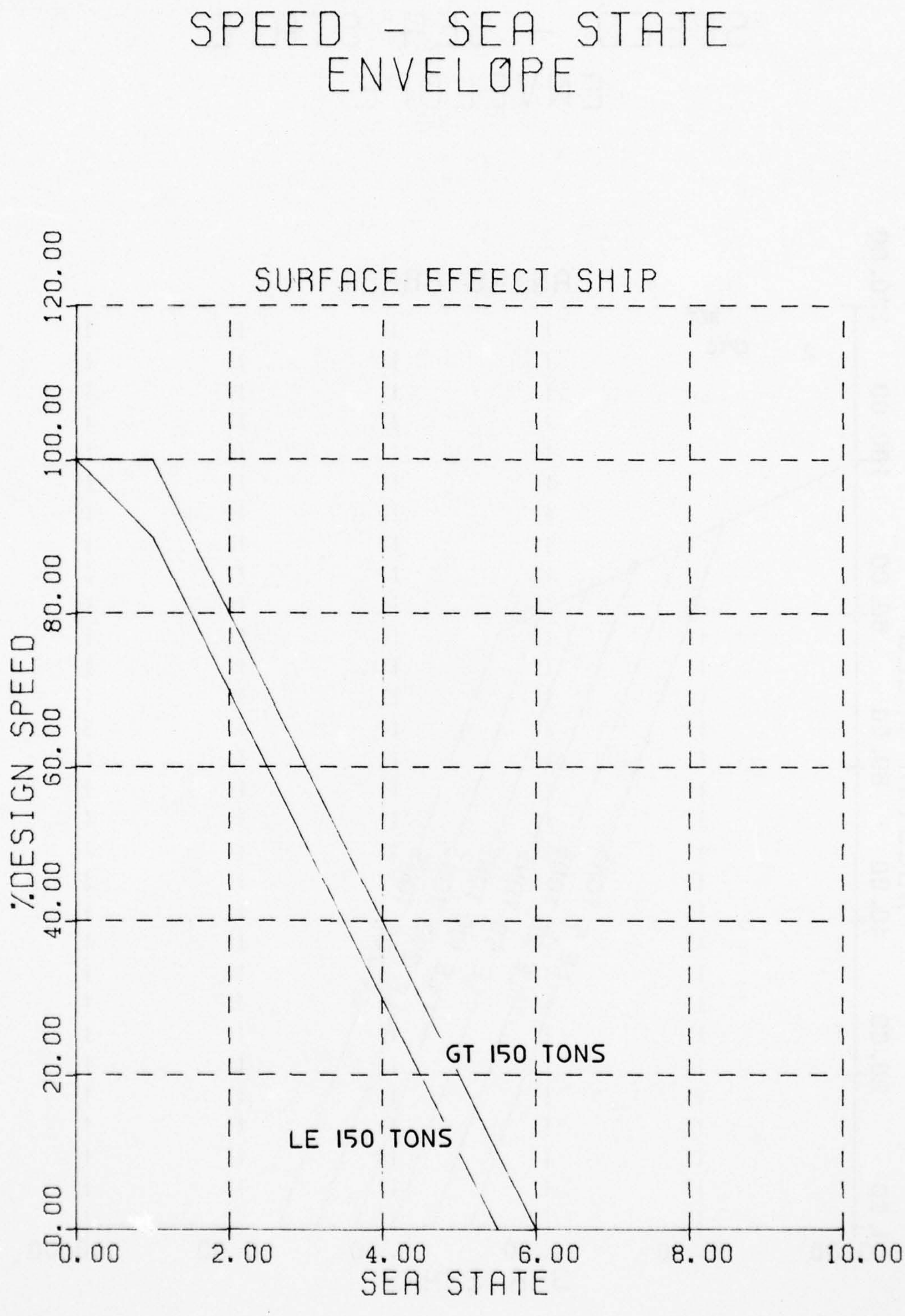
SPEED - SEA STATE
ENVELØPE
SURFACE EFFECT SHIP
%DESIGN SPEED
0.00
20.00
40.00
60.00
80.00
100.00
120.00
0.00
2.00
4.00
6.00
8.00
10.00
SEA STATE
GT 150 TONS
LE 150 TONS

FIGURE A-45

SPEED - SEA STATE ENVELOPE

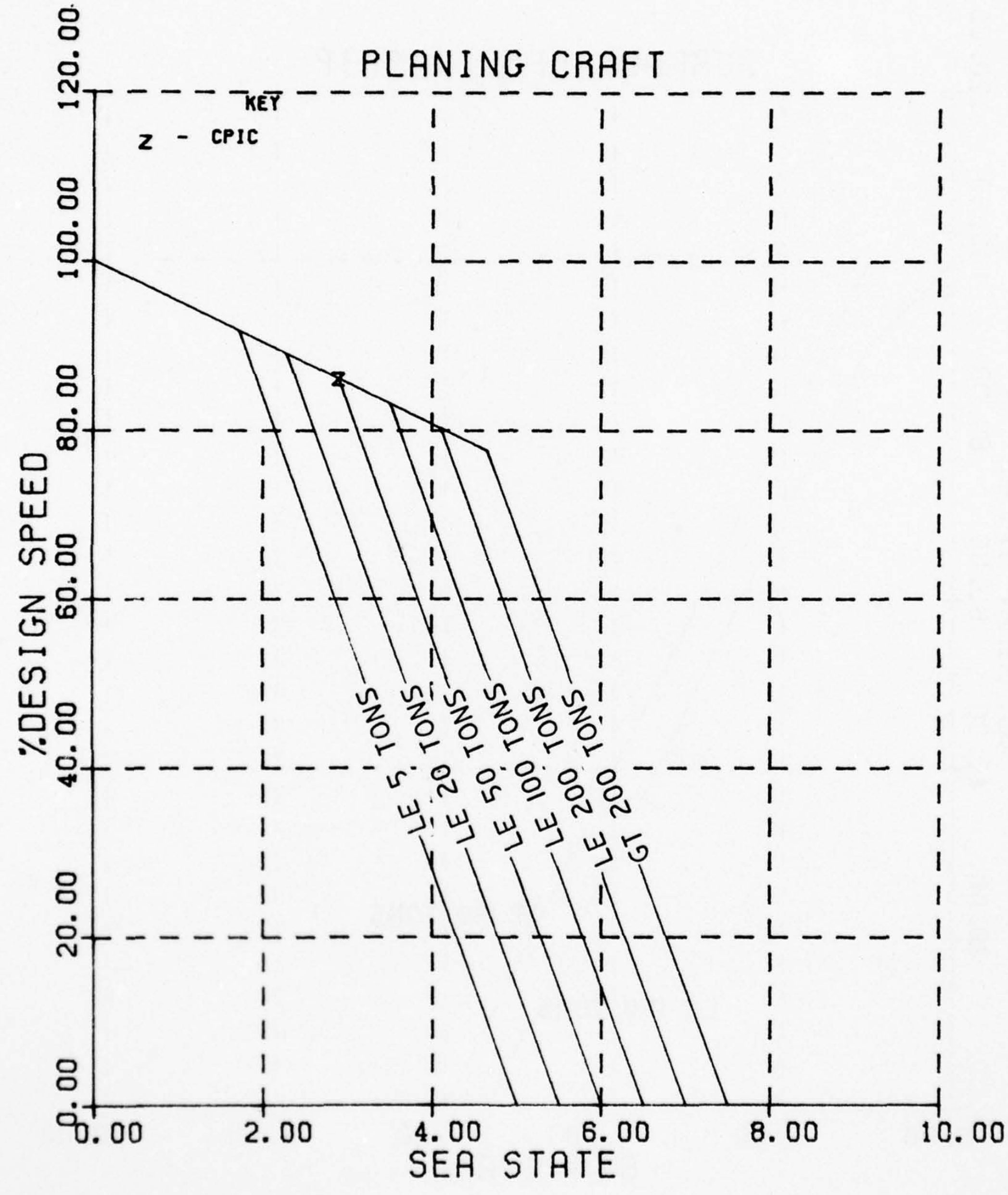

FIGURE A-46

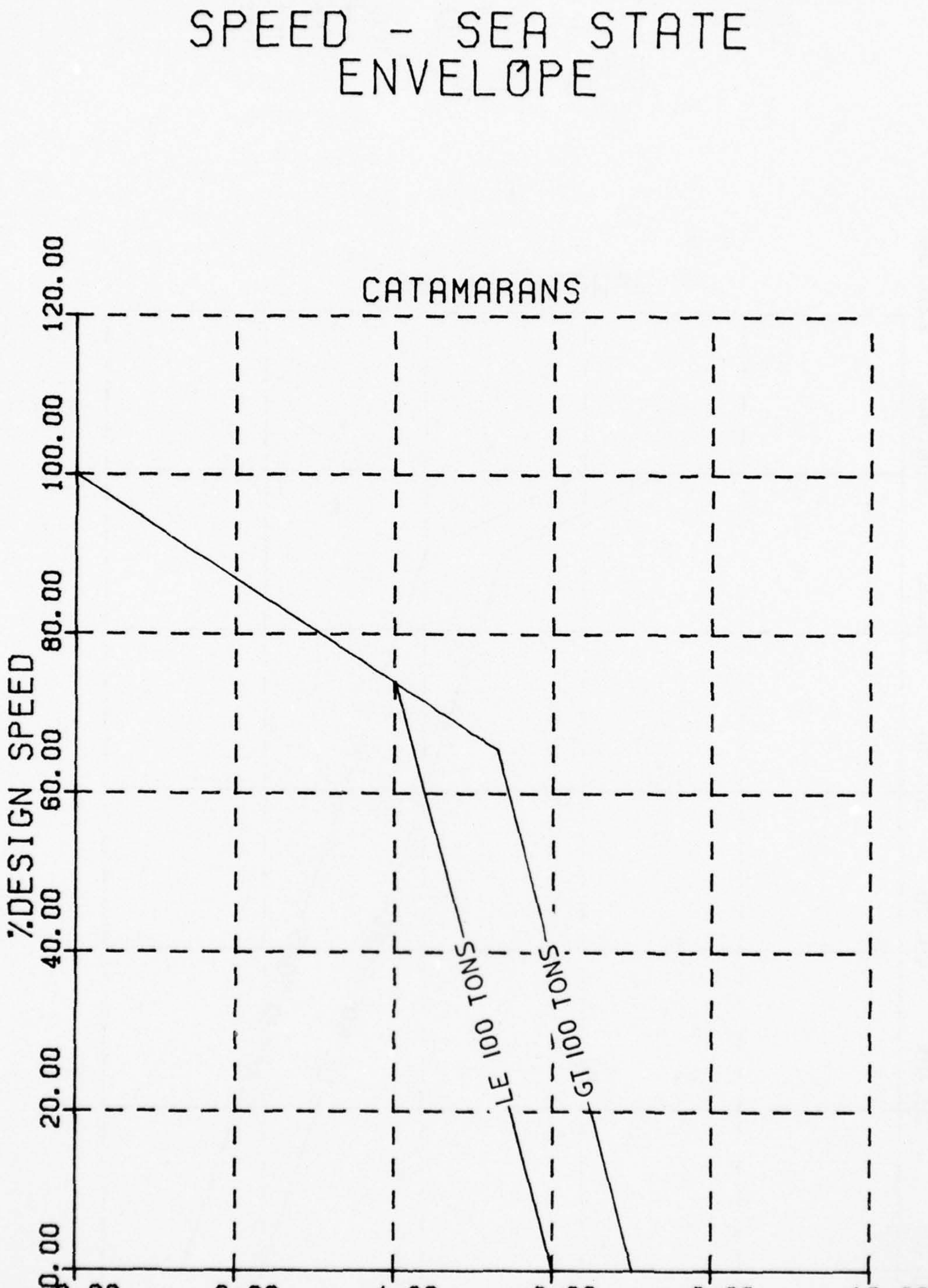
SPEED - SEA STATE
ENVELOPE
CATAMARANS
%DESIGN SPEED
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
2.00
4.00
6.00
8.00
10.00
SEA STATE
LE 100 TONS
GT 100 TONS

FIGURE A-47

SPEED - SEA STATE ENVELOPE

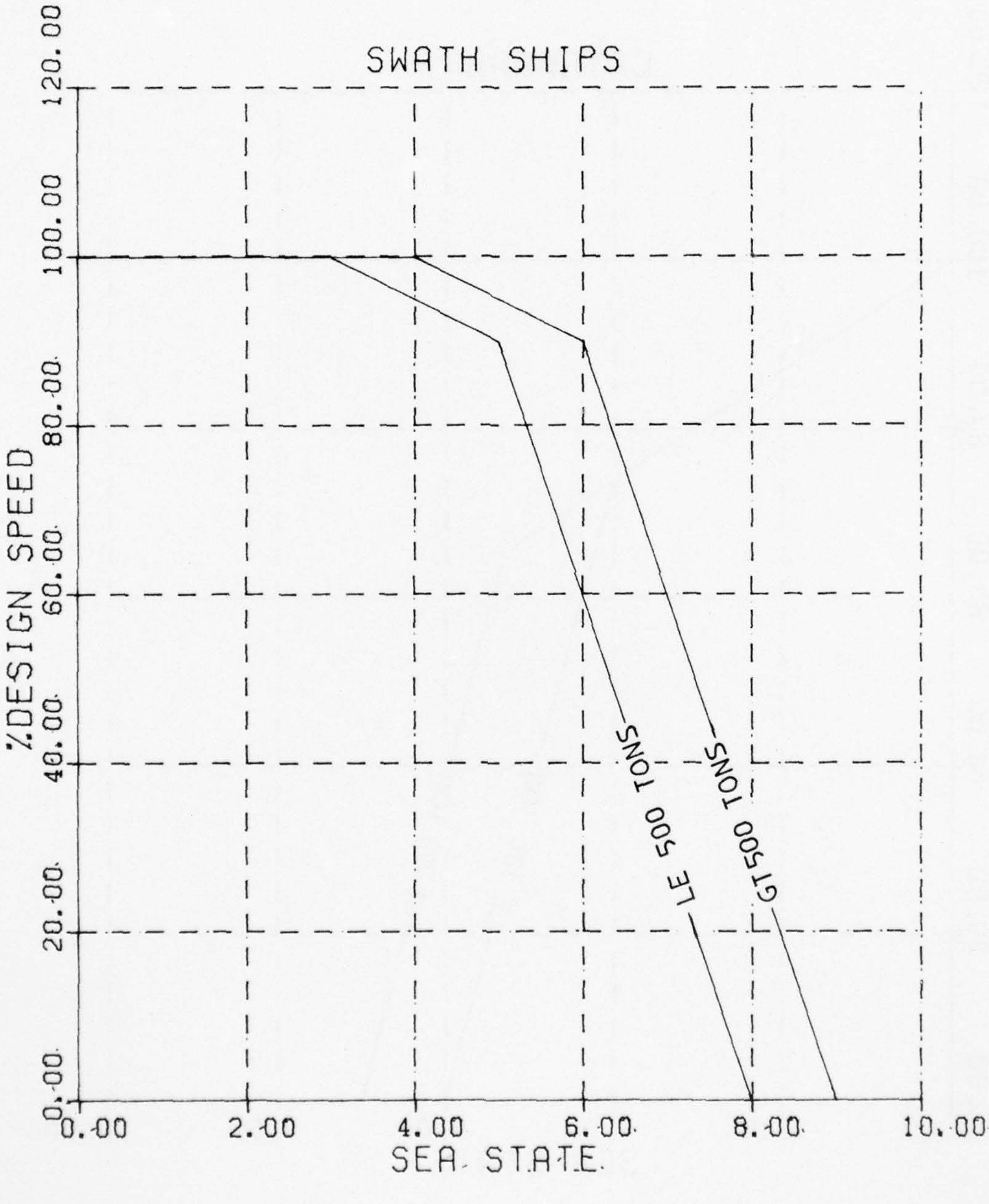

FIGURE A-48

SPEED - SEA STATE ENVELOPE

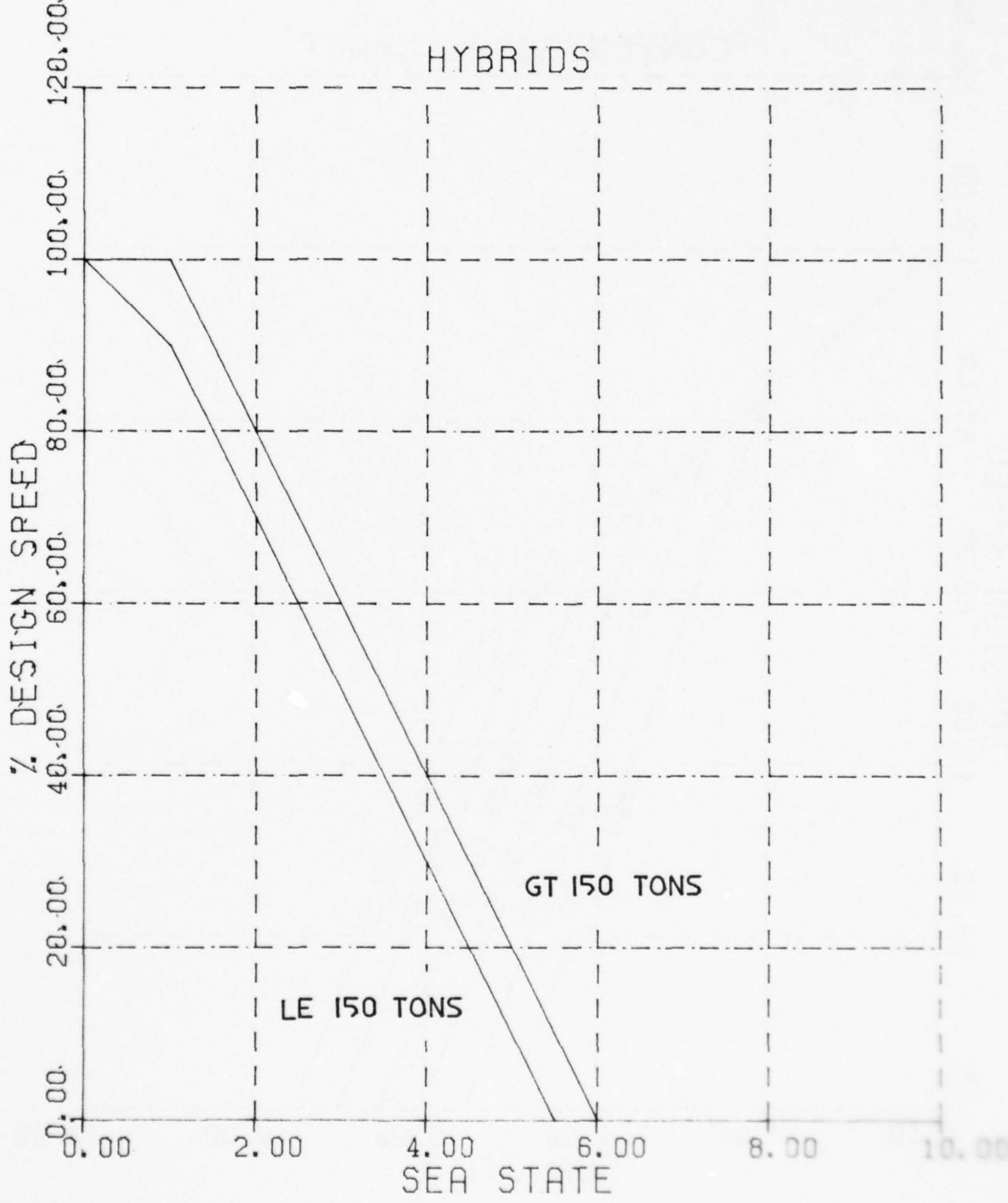

FIGURE A-49

AD-A051 392 COAST GUARD RESEARCH AND DEVELOPMENT CENTER GROTON CONN F/G 13/10
CUTTER RESOURCE EFFECTIVENESS EVALUATION MODEL. VOLUME II. THE --ETC(U)
JUN 77 A PASSERA, D S PRERAU, C W PRITCHETT

UNCLASSIFIED CGR/DC-16/77 USCG-D-46-77 NL

2 OF 2

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END
DATE
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DDC

SPEED - SEA STATE ENVELOPE

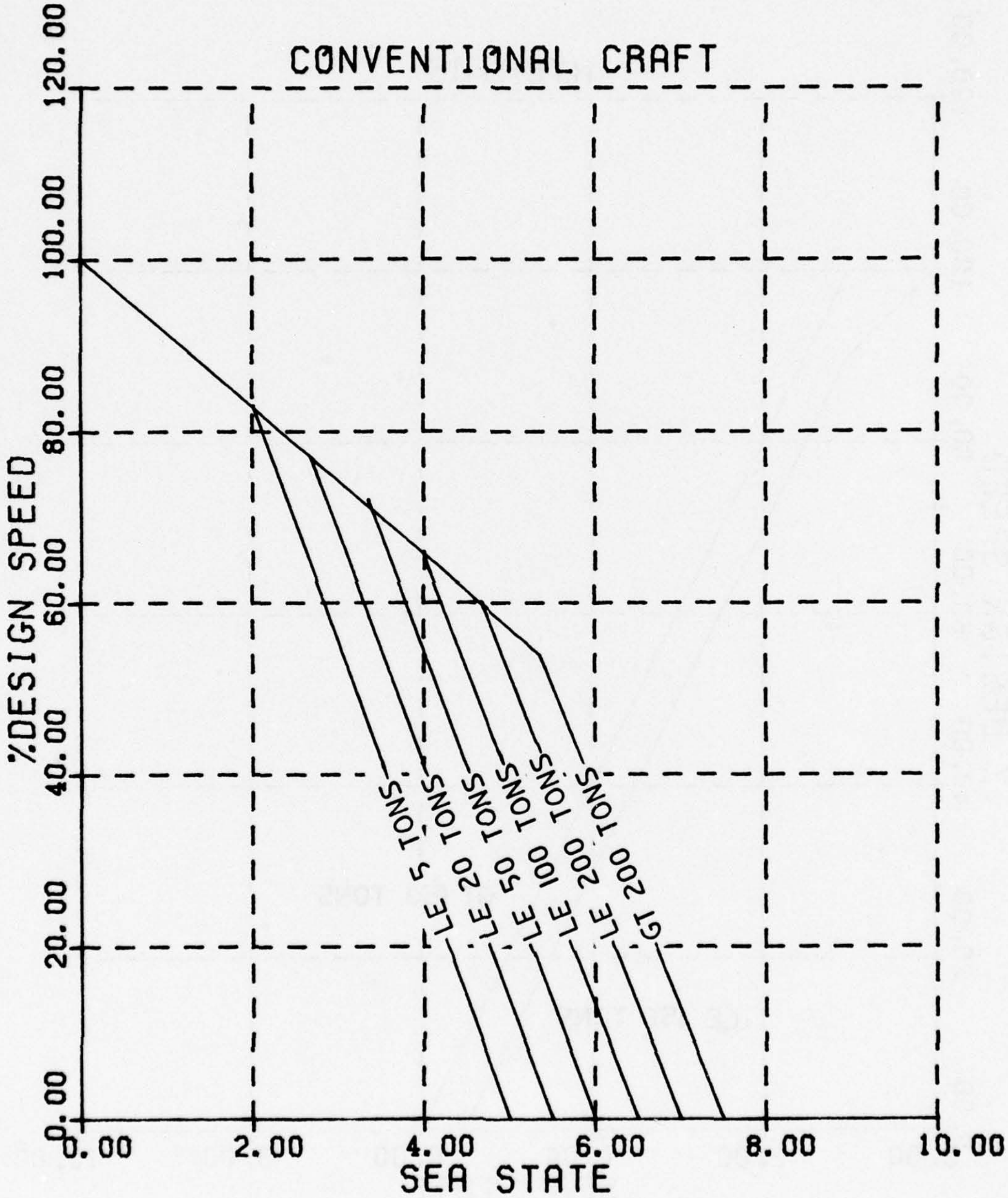


FIGURE A-50

SPEED - SEA STATE ENVELØPE

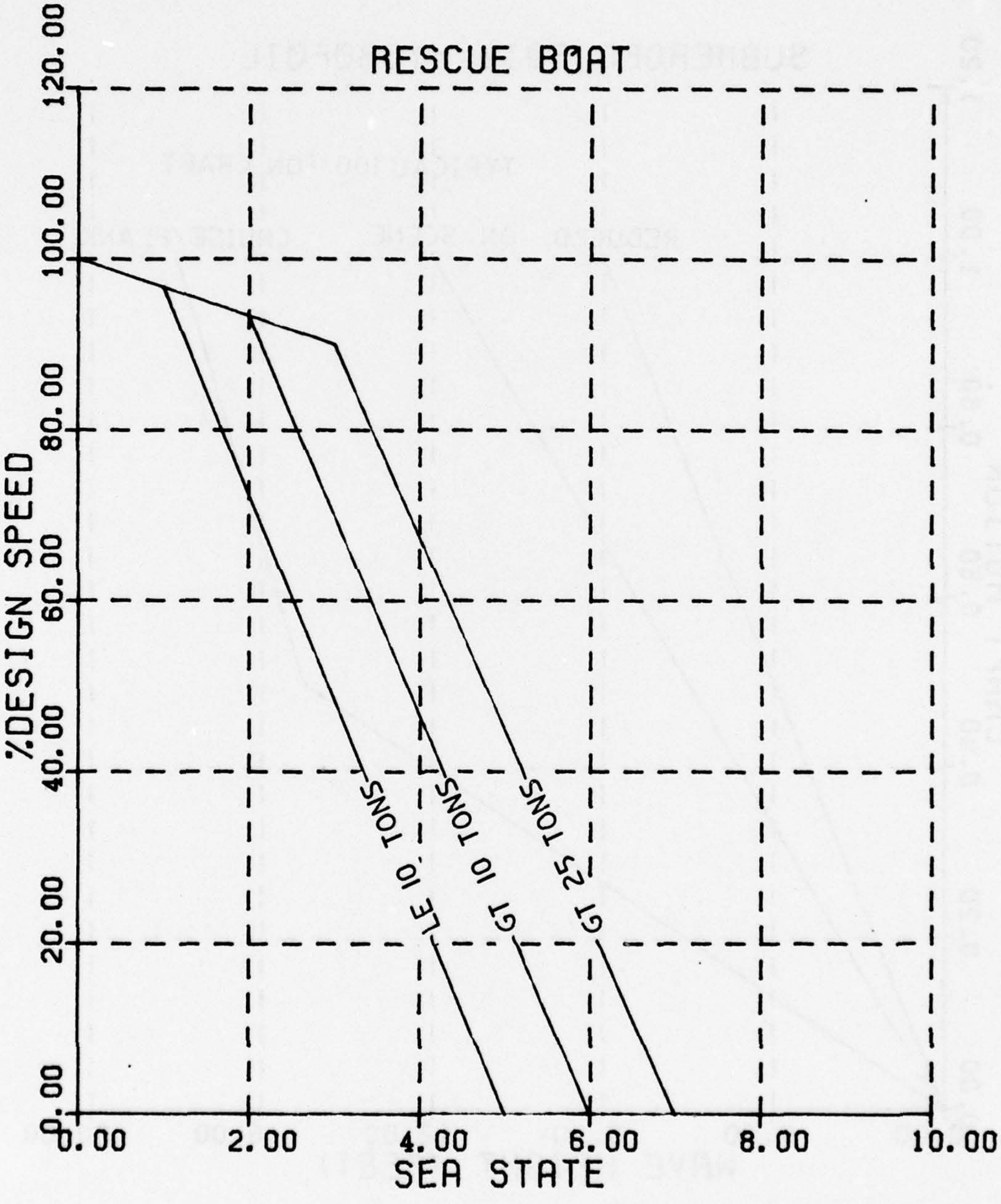


FIGURE A-51

CRAFT MOTION
-VS-
WAVE HEIGHT

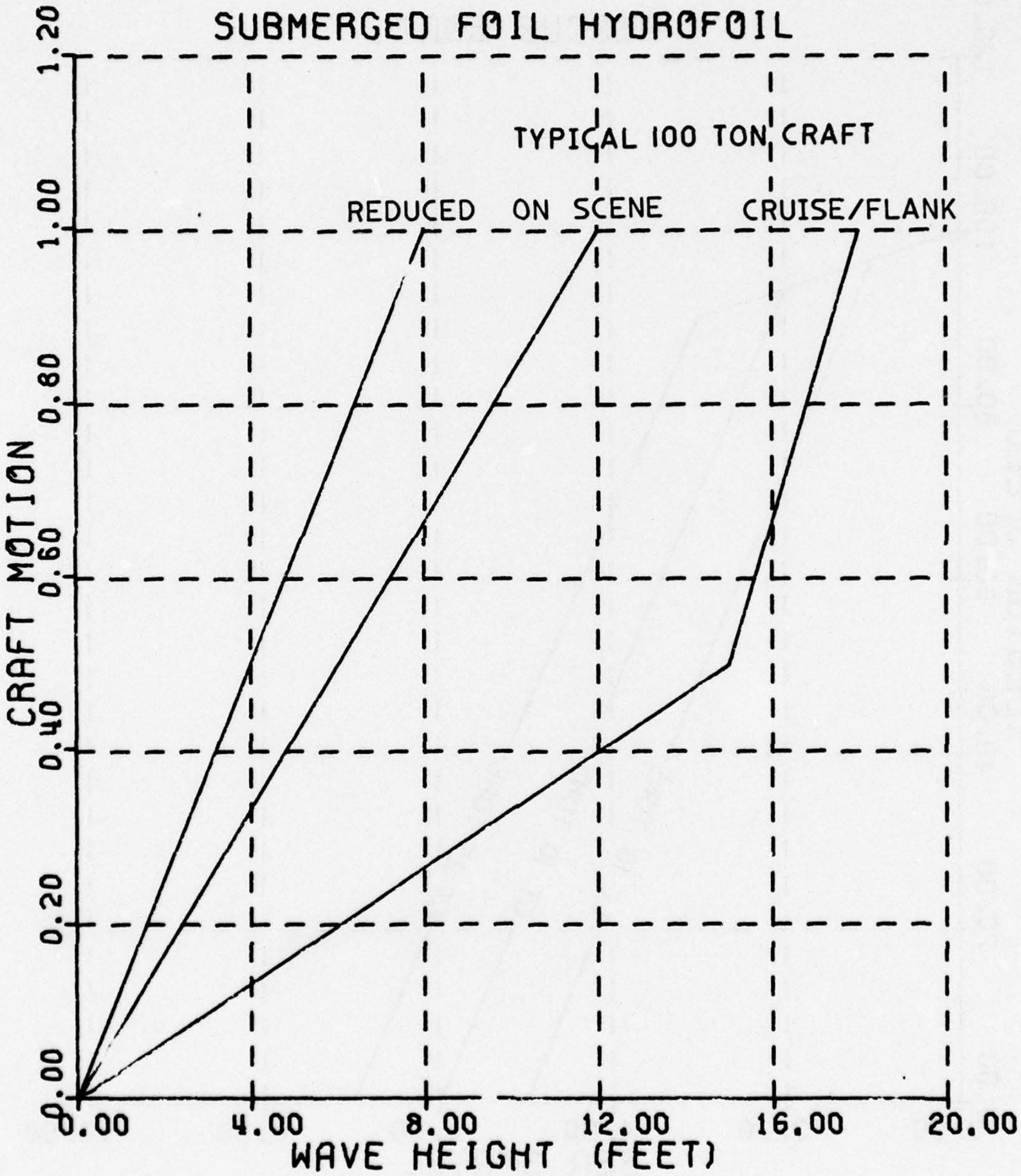


FIGURE A-52

CRAFT MOTION
-VS-
WAVE HEIGHT

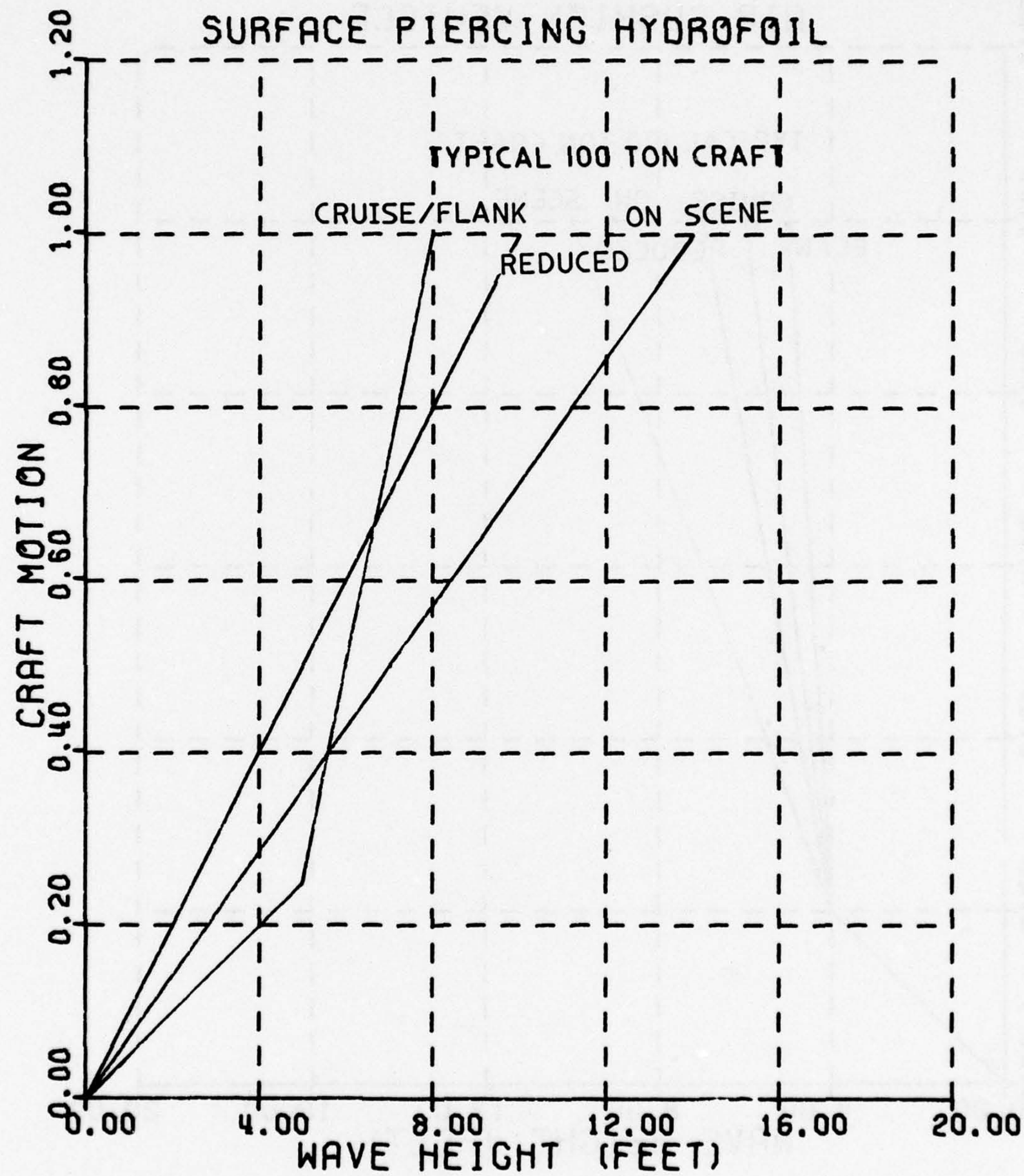


FIGURE A-53

CRAFT MOTION -VS- WAVE HEIGHT

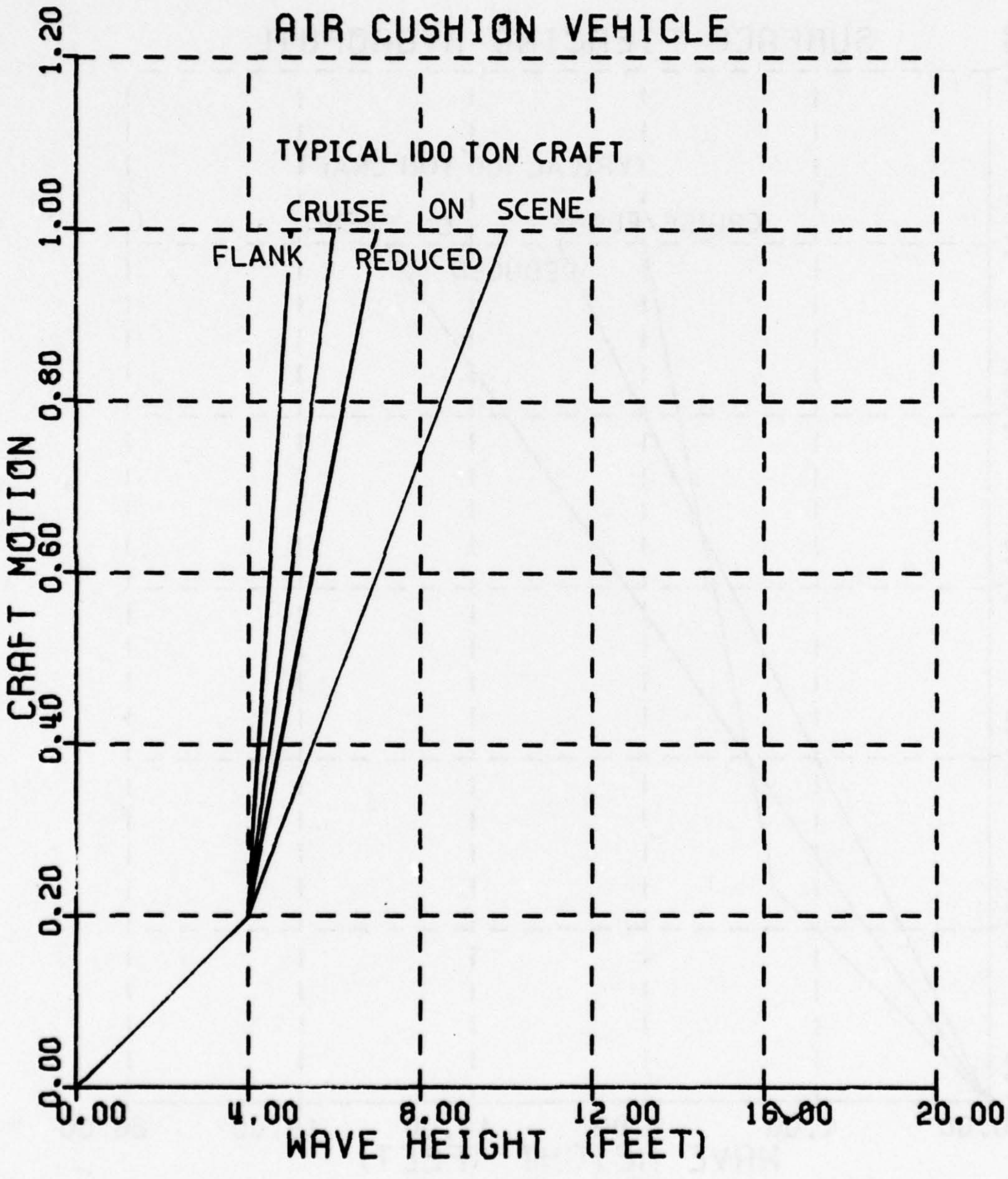


FIGURE A-54

CRAFT MOTION
-VS-
WAVE HEIGHT

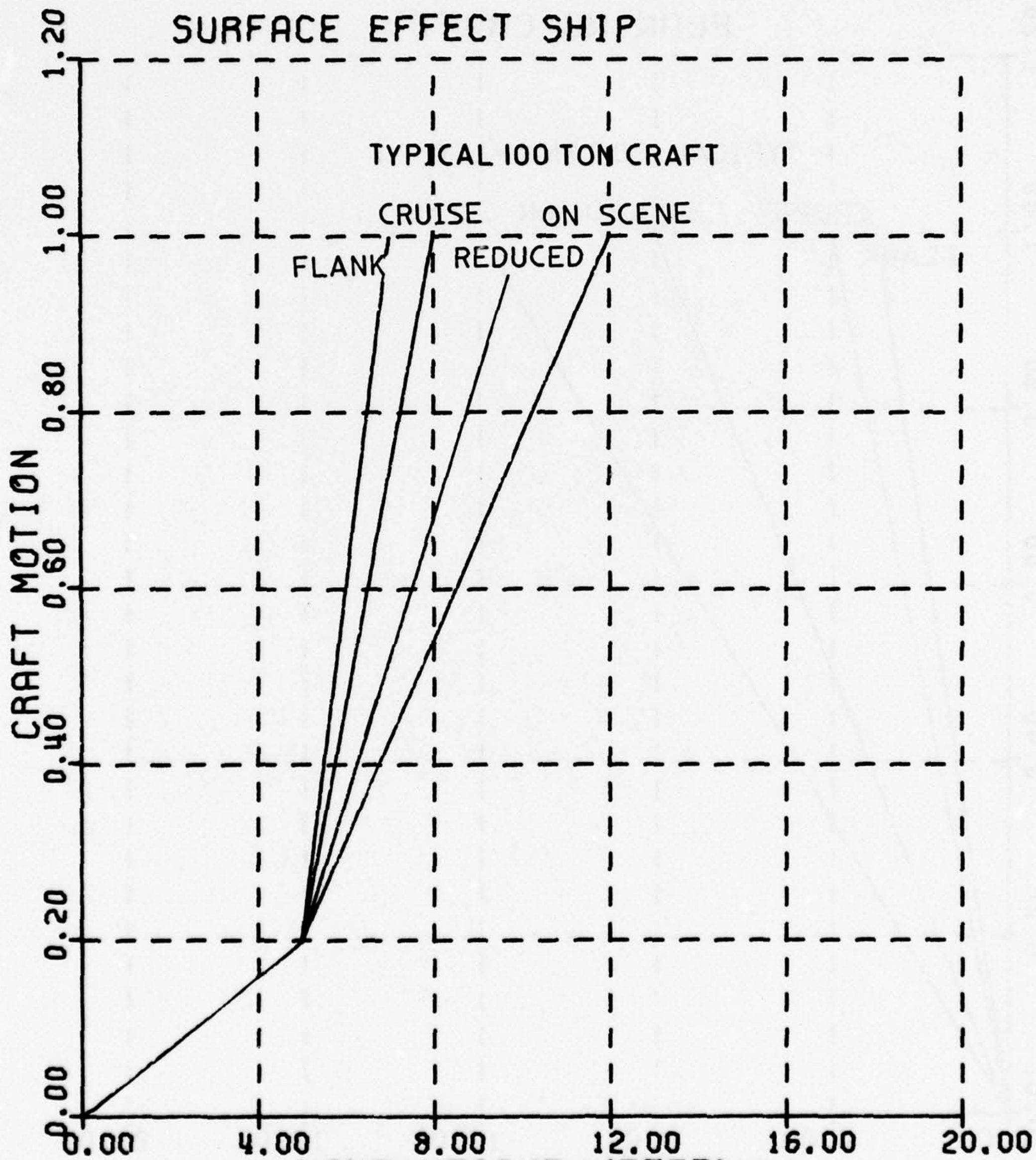


FIGURE A-55

CRAFT MOTION
-VS-
WAVE HEIGHT

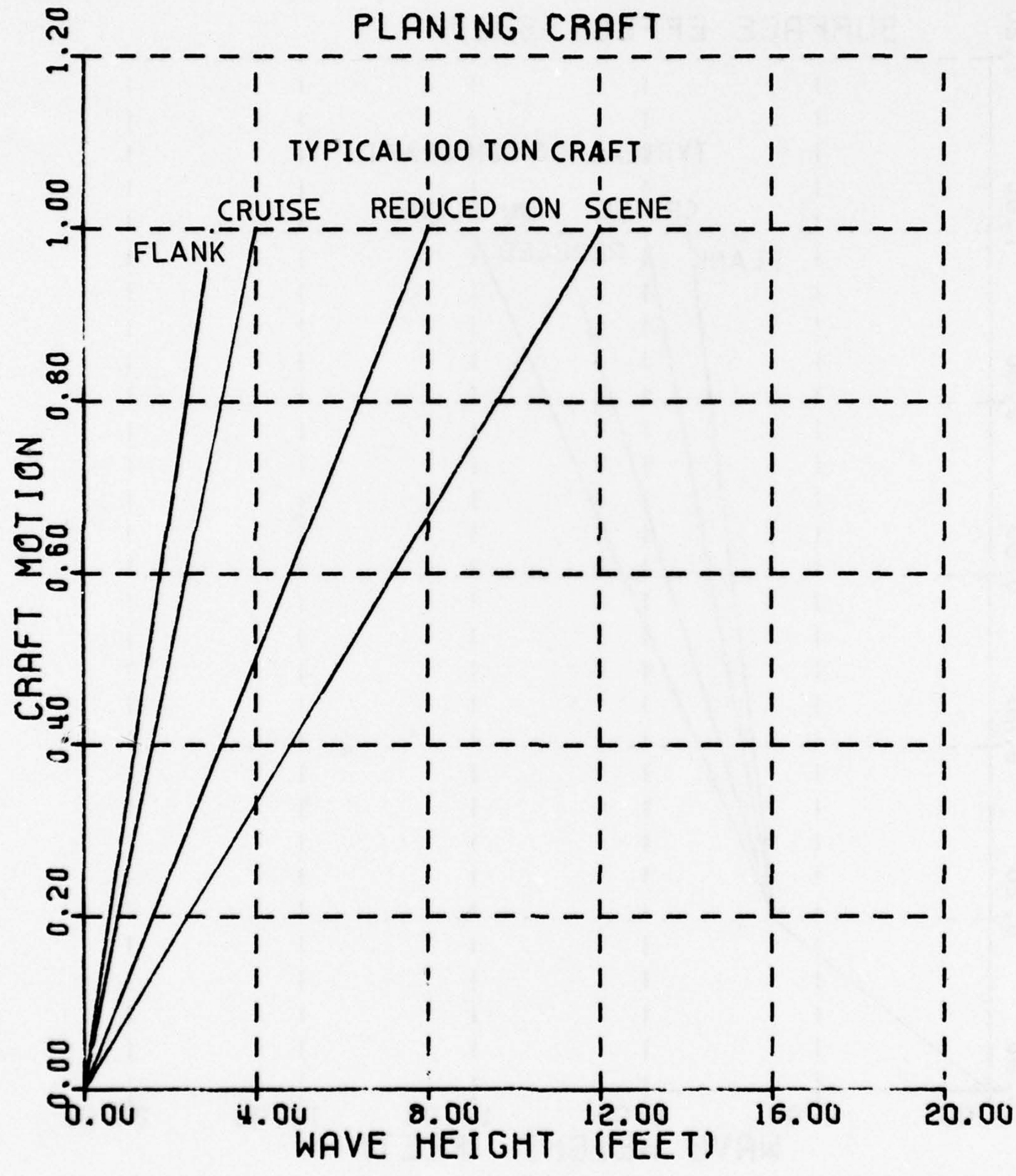


FIGURE A-56

CRAFT MOTION
-VS-
WAVE HEIGHT

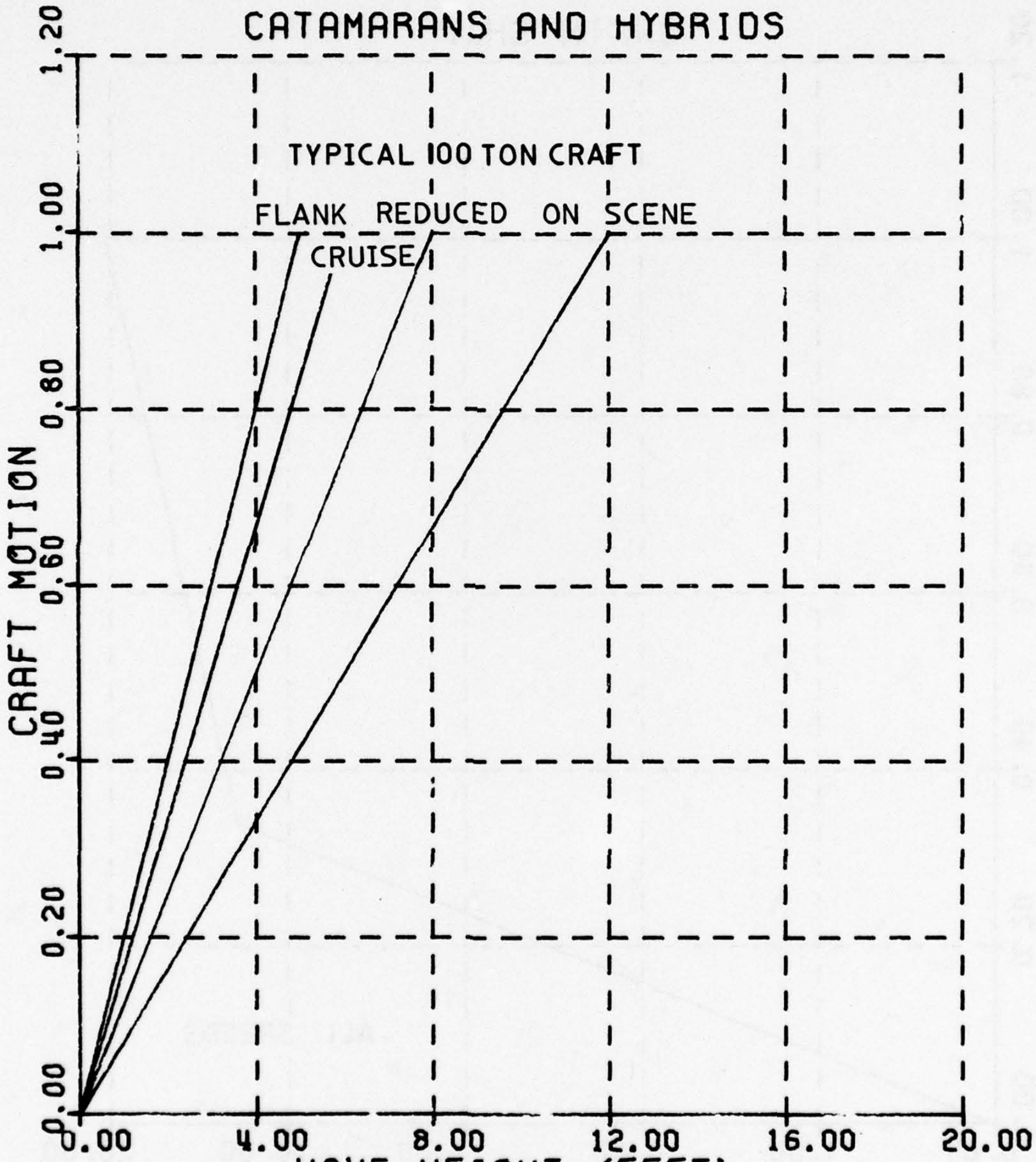


FIGURE A-57

CRAFT MOTION
-VS-
WAVE HEIGHT

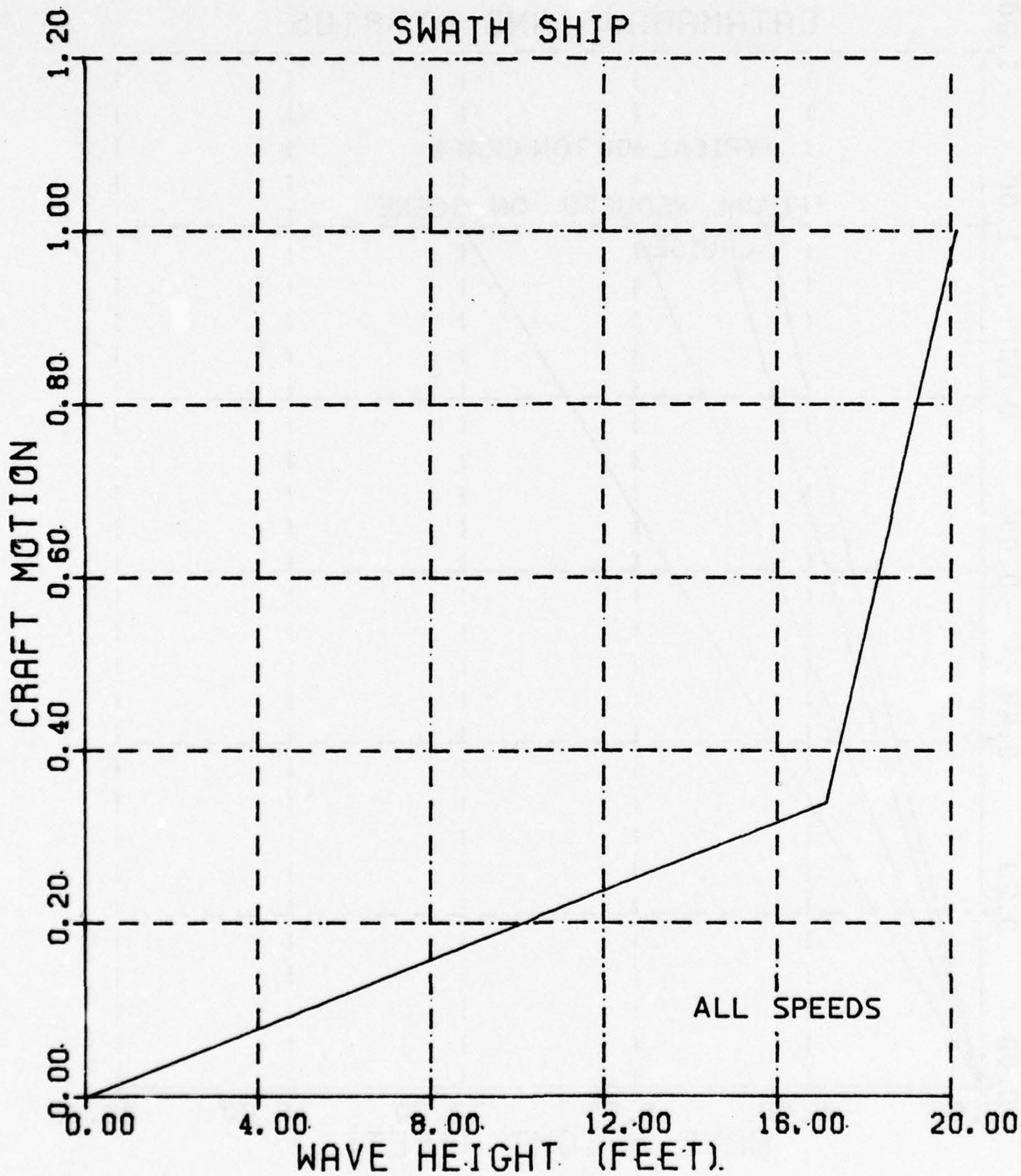


FIGURE A-58

CRAFT MOTION
-VS-
WAVE HEIGHT

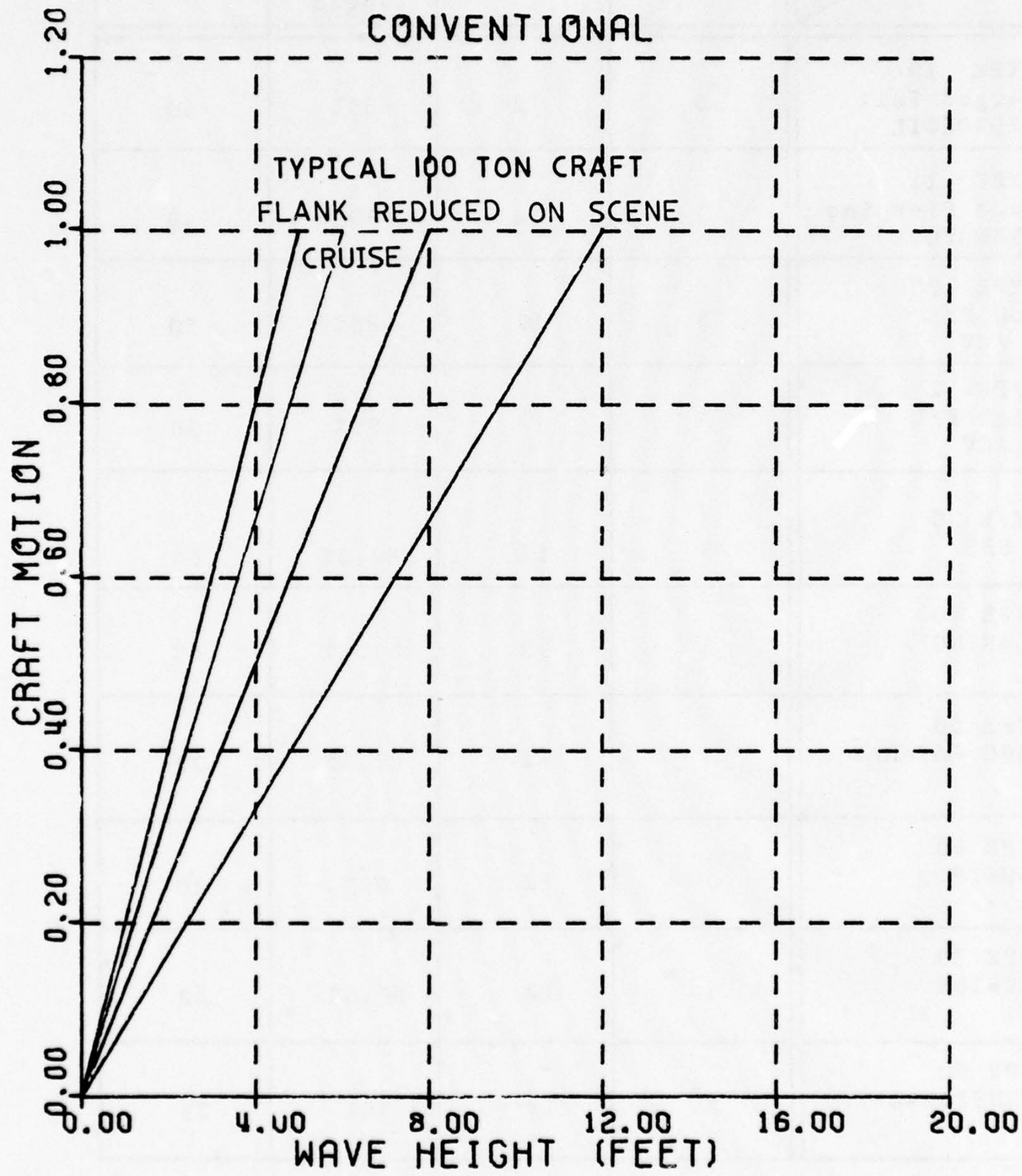


FIGURE A-59

TABLE A-1

VESSEL SPEED INFORMATION

SPEED / CRAFT TYPE	ON-SCENE Knots	REDUCED Knots	CRUISE % of Design Speed	BASE SPEED Knots
TYPE 10 Submerged Foil HYDROFOIL	5	12	85%	50
TYPE 11 Surface Piercing HYDROFOIL	5	12	90%	40
TYPE 20 Low P/L ACV	5	12	85%	50
TYPE 21 High P/L ACV	5	12	85%	50
TYPE 30 SES	5	12	87.5%	60
TYPE 40 PLANING	5	12	87.5%	45
TYPE 50 PLANING CATAMARAN	5	12	87.5%	30
TYPE 60 SWATH	5	12	60%	20
TYPE 70 HYBRIDS	5	12	87.5%	40
TYPE 80 CONVENTIONAL	5	12	50%	25

Base Speed--Maximum calm-water speed upon which craft characteristics are based.

Design Speed--Maximum calm-water speed entered by user into the program

TABLE A-2

VESSEL PROPULSION MODES

CRAFT TYPE \ SPEED	ON-SCENE	REDUCED	CRUISE	FLANK
TYPE 10 Submerged Foil HYDROFOIL	DE	GT	GT	GT
TYPE 11 Surface Piercing HYDROFOIL	DE	DE	DE	DE
TYPE 20 Low P/L ACV	GT	GT	GT	GT
TYPE 21 High P/L ACV	GT	GT	GT	GT
TYPE 30 SES	GT	GT	GT	GT
TYPE 40 PLANING	DE	GT	GT	GT
TYPE 50 PLANING CATAMARAN	DE	DE	DE	DE
TYPE 60 SWATH	GT	GT	GT	GT
TYPE 70 HYBRIDS	DE	DE	DE	GT
TYPE 80 CONVENTIONAL	DE	DE	DE	DE

TABLE A-3

VESSEL DESIGN INFORMATION

CRAFT TYPE	DRAFT TO LENGTH RATIO (D/L)	LENGTH TO BEAM RATIO (L/B)	DECK AREA COEFFICIENT (da)	SURVIVABILITY CONSTANT
TYPE 10 Submerged Foil HYDROFOIL	0.20	4.0	0.25	3.0
TYPE 11 Surface Piercing HYDROFOIL	0.15	4.5	0.25	3.0
TYPE 20 Low P/L ACV	0.01	2.0	0.50	2.0
TYPE 21 High P/L ACV	0.01	2.0	0.50	2.0
TYPE 30 SES	0.05	3.0	0.75	3.0
TYPE 40 PLANING	0.06	5.5	0.25	3.0
TYPE 50 PLANING CATAMARAN	0.05	2.5	0.40	3.5
TYPE 60 SWATH	0.10	3.0	0.55	4.0
TYPE 70 HYBRIDS	0.06	3.0	0.30	3.0
TYPE 80 CONVENTIONAL	0.06	5.0	0.25	3.0

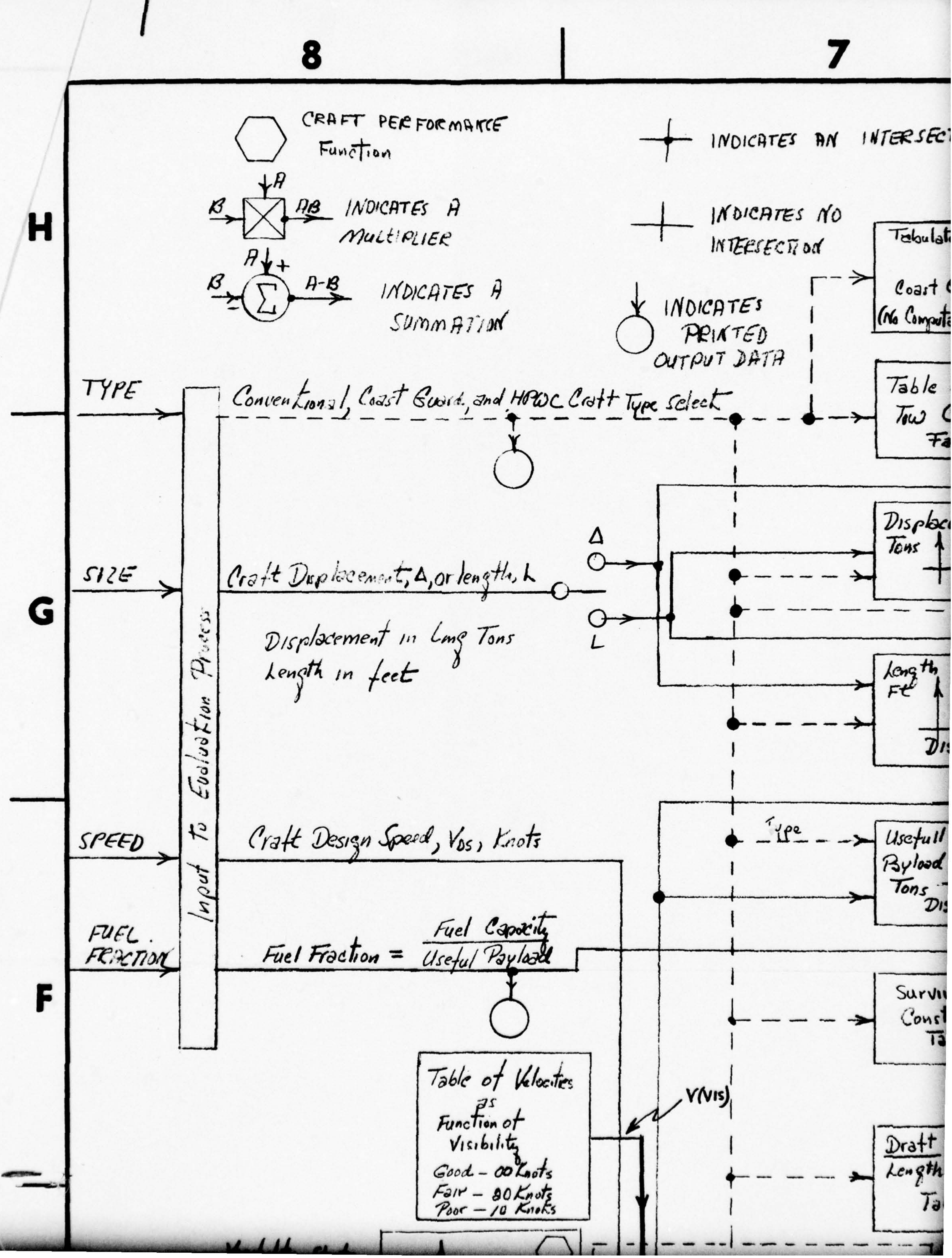
TABLE A-4

VESSEL DESIGN INFORMATION

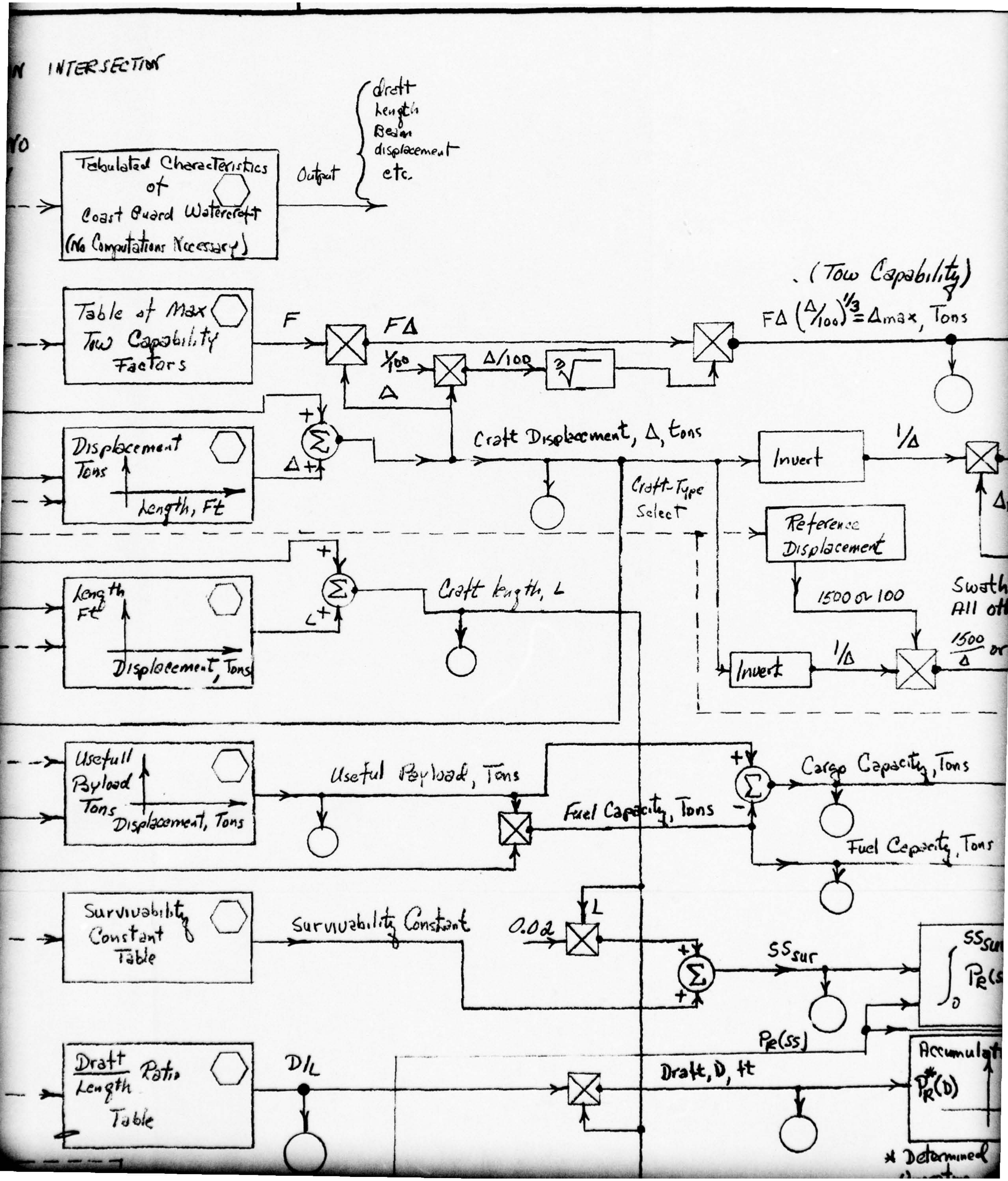
CRAFT TYPE \ ITEM	ANGULAR TURNING RATE deg/sec	TOWING FACTOR F
TYPE 10 Submerged Foil HYDROFOIL	8.0	10
TYPE 11 Surface Piercing HYDROFOIL	3.0	10
TYPE 20 Low P/L ACV	2.0	2
TYPE 21 High P/L ACV	2.0	2
TYPE 30 SES	1.5	10
TYPE 40 PLANING	4.0	10
TYPE 50 PLANING CATAMARAN	3.0	10
TYPE 60 SWATH	3.0	5
TYPE 70 HYBRIDS	3.0	10
TYPE 80 CONVENTIONAL	3.0	10

APPENDIX B

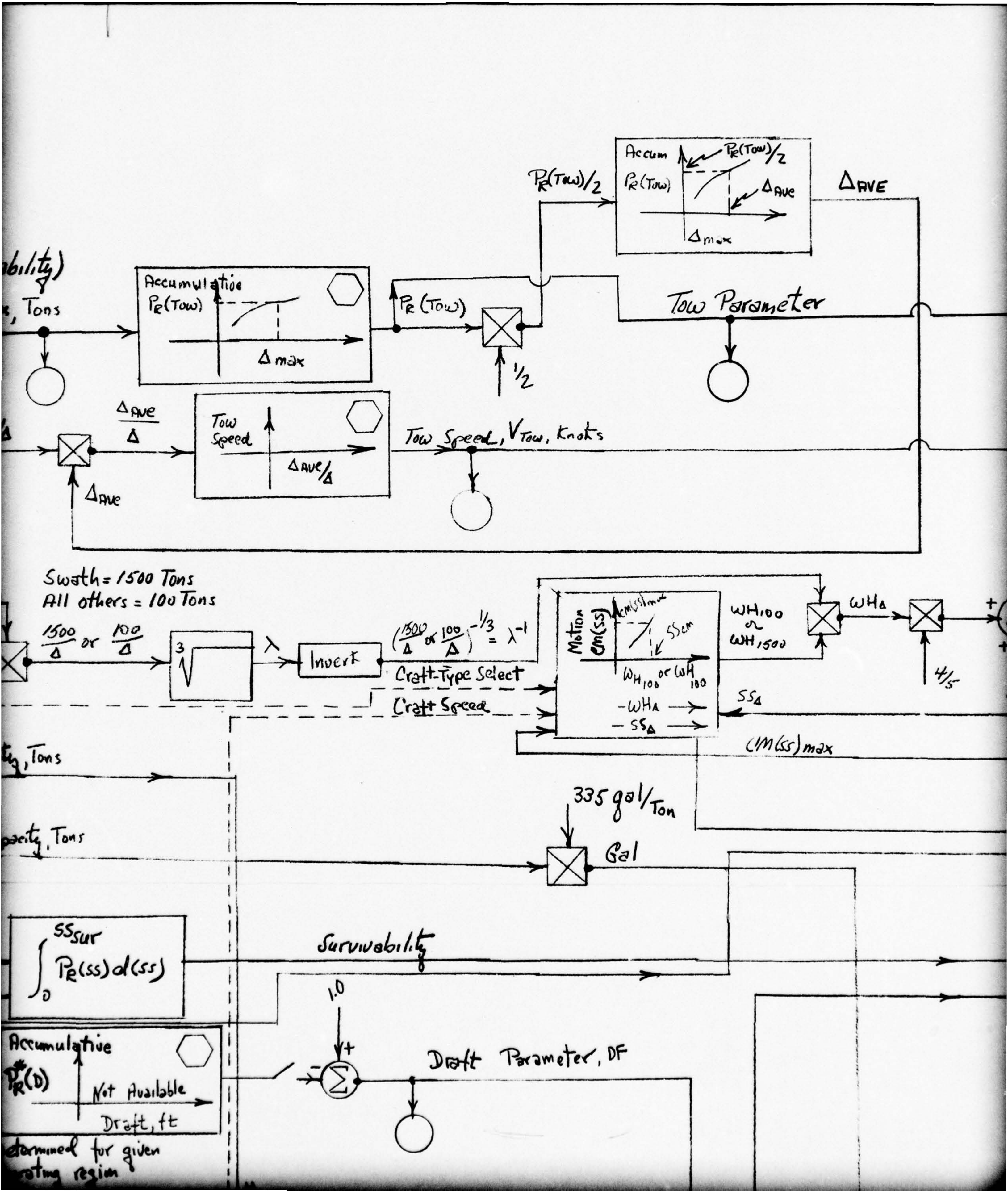
SCHEMATIC DIAGRAM FOR CRAFT/TASK EVALUATIONS



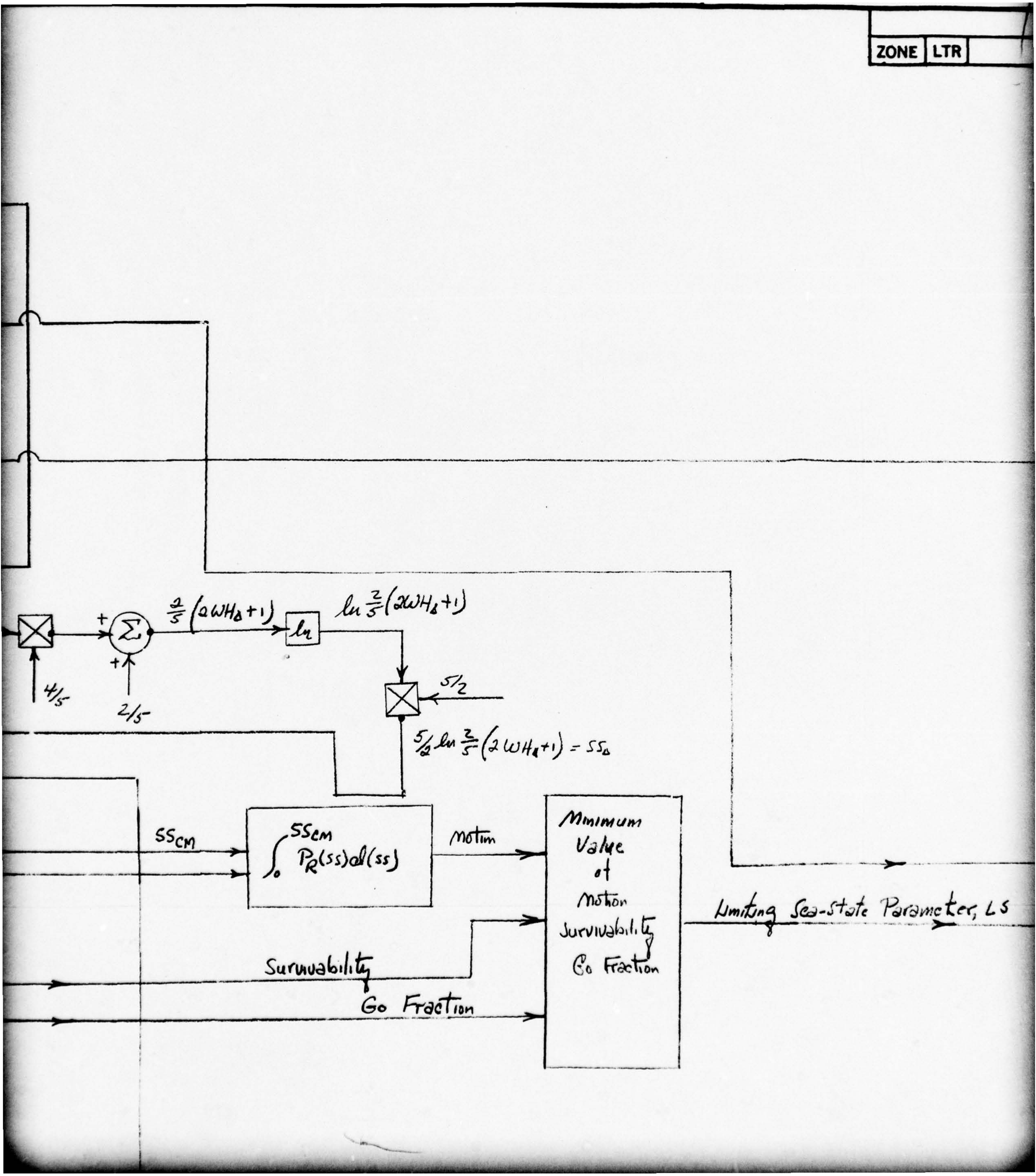
8
7
H
G
F
CRAFT PERFORMANCE Function
A
B
AB
INDICATES A MULTIPLIER
A-B
INDICATES A SUMMATION
INDICATES AN INTERSECT
INDICATES NO INTERSECTION
INDICATES PRINTED OUTPUT DATA
TYPE
SIZE
SPEED
FUEL FRACTION
Input to Evaluation Process
Conventional, Coast Guard, and HPWC Craft Type select
Craft Displacement, Δ, or length, L
Δ
L
Displacement in Long Tons
Length in feet
Craft Design Speed, V_{DS}, Knots
Fuel Fraction = Fuel Capacity / Useful Payload
Table of Velocities as Function of Visibility
Good – 00 Knots
Fair – 20 Knots
Poor – 10 Knots
V(VIS)
Type
Coast G
(No Computa
Table
Tow
Displac
Tons
Length Ft
Usefull Payload Tons
Surviv
Const
Draft
Length



INTERSECTION
Tabulated Characteristics of Coast Guard Watercraft (No Computations Necessary)
Output
draft
length
Beam
displacement
etc.
(Tow Capability)
Table of Max Tow Capability Factors
F
FΔ
1/100
Δ
Δ/100
FΔ (Δ/100)^1/3 = Δmax, Tons
Displacement Tons
Length, Ft
Craft Displacement, Δ, tons
Invert
1/Δ
Craft-Type Select
Reference Displacement
1500 or 100
Length Ft
Displacement, Tons
Craft length, L
Invert
1/Δ
Usefull Payload Tons
Displacement, Tons
Useful Payload, Tons
Fuel Capacity, Tons
Cargo Capacity, Tons
Fuel Capacity, Tons
Survivability Constant Table
Survivability Constant
0.02
L
SSsur
PR(SS)
Draft/Length Ratio Table
D/L
Draft, D, ft
Accumulat
PR*(D)
* Determined

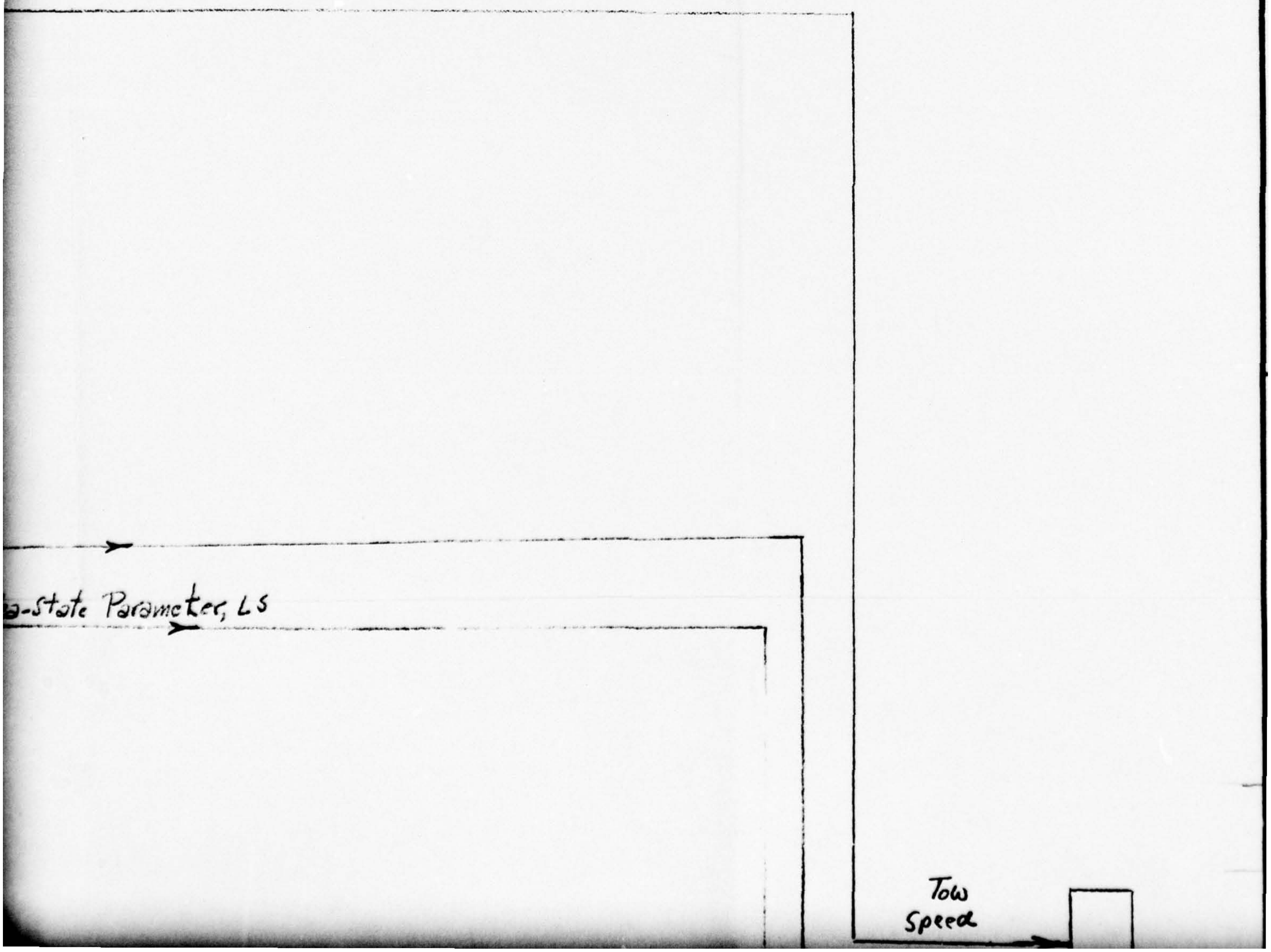


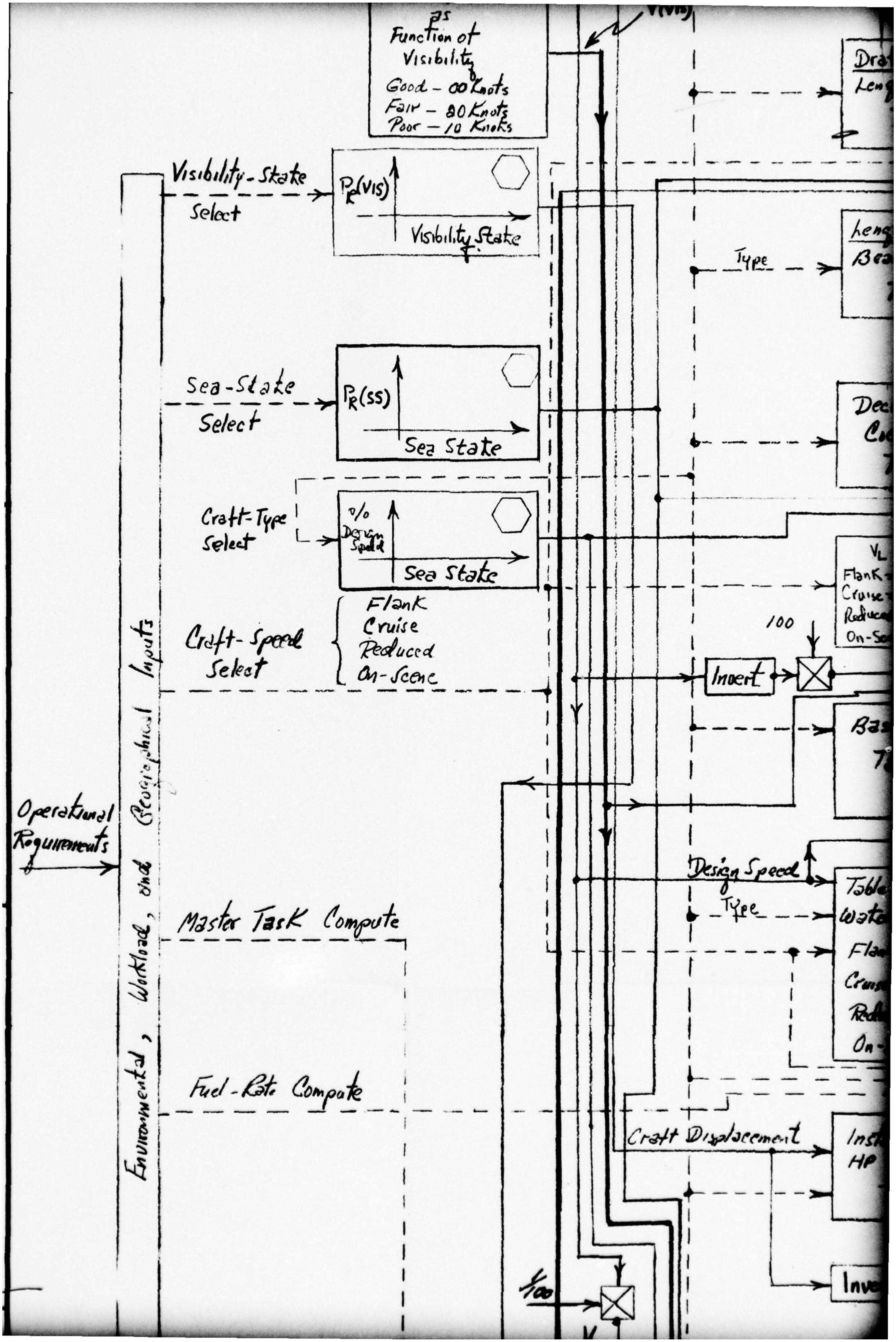
Accum
$P_R(Tow)/2$
$P_R(Tow)$
Δ_{AVE}
Δ_{max}
ability)
, Tons
Accumulative
$P_R(Tow)$
Δ max
$P_R(Tow)$
1/2
Tow Parameter
Δ_{AVE}/Δ
Tow Speed
Δ_{AVE}/Δ
Tow Speed, V_{Tow}, Knots
Δ_{AVE}
Swath = 1500 Tons
All others = 100 Tons
$\frac{1500}{\Delta}$ or $\frac{100}{\Delta}$
λ
Invert
$\left(\frac{1500}{\Delta} \text{ or } \frac{100}{\Delta}\right)^{-1/3} = \lambda^{-1}$
Craft-Type Select
Craft Speed
Motion CM(SS)
SS_{CM}
WH_{100} or WH_{100}
$-WH_\Delta \rightarrow$
$-SS_\Delta \rightarrow$
WH_{100} or WH_{1500}
WH_Δ
4/5
SS_Δ
$(CM(SS))_{max}$
ty, Tons
335 gal/Ton
pacity, Tons
Gal
$\int_0^{SS_{sur}} P_R(ss)\,d(ss)$
Survivability
1.0
Accumulative
$P_R^*(D)$
Not Available
Draft, ft
Draft Parameter, DF
etermined for given
rating region



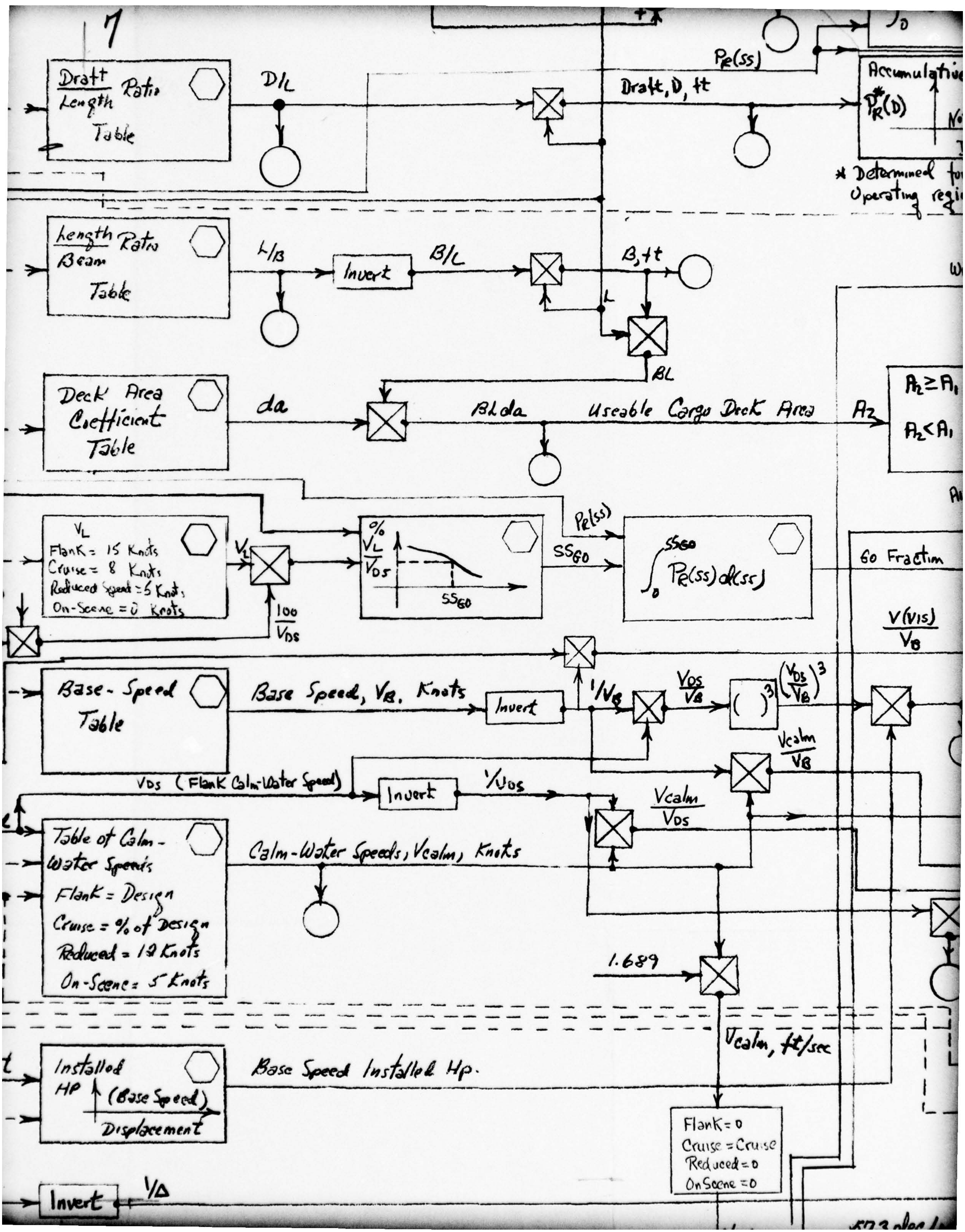
ZONE
LTR
4/5
2/5
$\frac{2}{5}(2WH_s+1)$
ln
$\ln\frac{2}{5}(2WH_s+1)$
5/2
$\frac{5}{2}\ln\frac{2}{5}(2WH_s+1) = SS_s$
SS_{CM}
$\int_0^{SS_{CM}} P_R(ss)\,d(ss)$
Motion
Minimum Value of Motion Survivability Go Fraction
Limiting Sea-state Parameter, LS
Survivability
Go Fraction

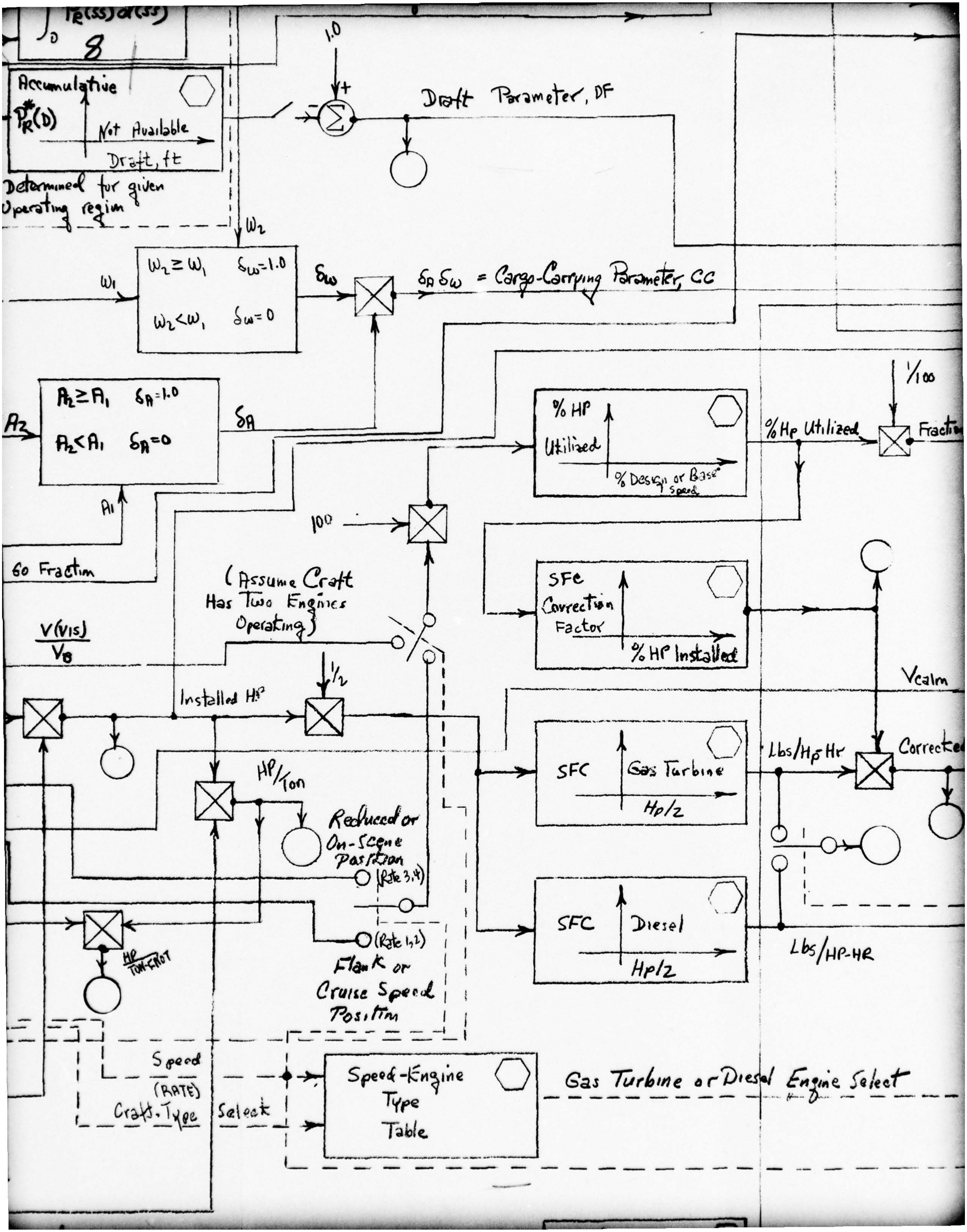
REVISIONS						
ZONE	LTR	DESCRIPTION	DR	CHK	DATE	APPROVED

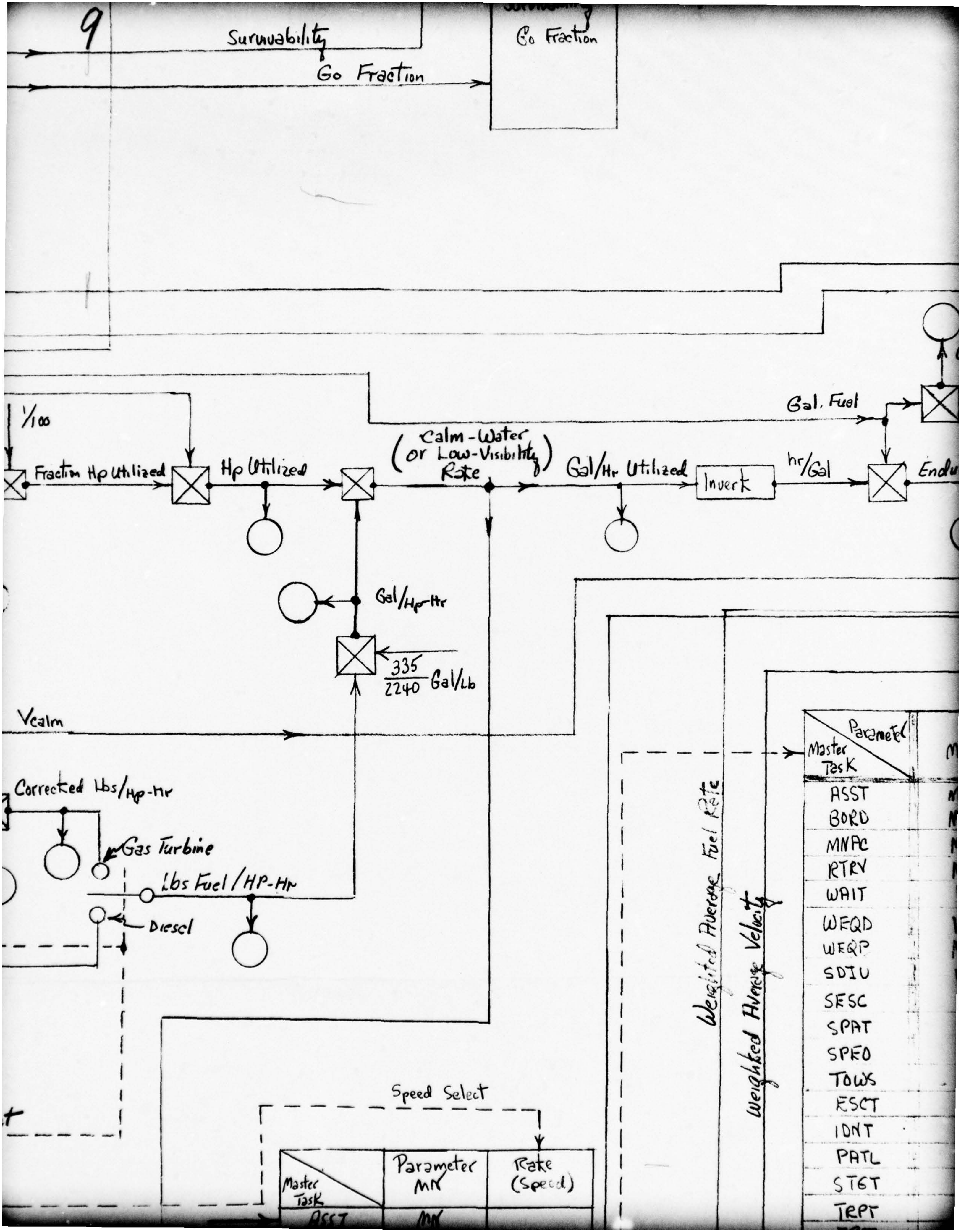




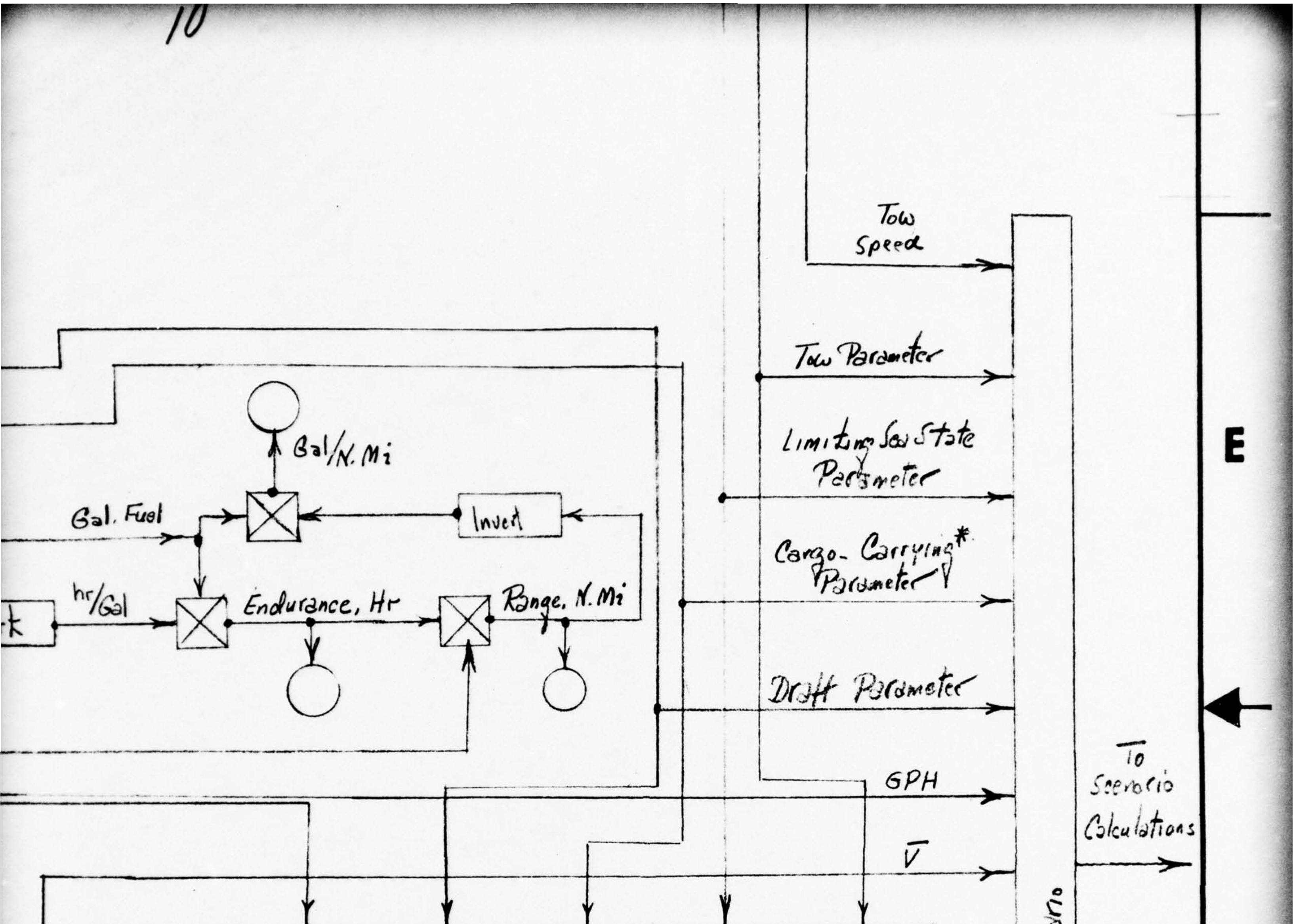
as Function of Visibility
Good - 00 Knots
Fair - 20 Knots
Poor - 10 Knots
V(VIS)
Visibility-State Select
P_R(VIS)
Visibility State
Type
Sea-State Select
P_R(SS)
Sea State
Craft-Type Select
% Design Speed
Sea State
Craft-Speed Select
Flank
Cruise
Reduced
On-Scene
V_L
100
Invert
Operational Requirements
Environmental, Workload, and Geographical Inputs
Design Speed
Type
Master Task Compute
Fuel-Rate Compute
Craft Displacement
1/100
V


7
Draft Length Ratio Table
D/L
Draft, D, ft
$P_R(SS)$
Accumulative
$P^*_R(D)$
* Determined for Operating region
Length Beam Ratio Table
L/B
Invert
B/L
B, ft
L
BL
Deck Area Coefficient Table
da
BLda
Useable Cargo Deck Area
A_2
$A_2 \geq A_1$
$A_2 < A_1$
V_L
Flank = 15 Knots
Cruise = 8 Knots
Reduced Speed = 5 Knots
On-Scene = 0 Knots
%
V_L / V_{DS}
SS_{GO}
$P_R(SS)$
$\int_0^{SS_{GO}} P_R(SS)\,d(SS)$
Go Fraction
100 / V_{DS}
$V(V_{IS}) / V_B$
Base-Speed Table
Base Speed, V_B, Knots
Invert
$1/V_B$
V_{DS}/V_B
$(\ )^3$
$(V_{DS}/V_B)^3$
V_{calm}/V_B
V_{DS} (Flank Calm-Water Speed)
Invert
$1/V_{DS}$
V_{calm}/V_{DS}
Table of Calm-Water Speeds
Flank = Design
Cruise = % of Design
Reduced = 12 Knots
On-Scene = 5 Knots
Calm-Water Speeds, V_{calm}, Knots
1.689
V_{calm}, ft/sec
Installed HP (Base Speed) Displacement
Base Speed Installed Hp.
Flank = 0
Cruise = Cruise
Reduced = 0
On Scene = 0
Invert
$1/\Delta$


8
Accumulative
$P_R^*(D)$
Not Available
Draft, ft
Determined for given Operating regime
1.0
Draft Parameter, DF
W_2
W_1
$W_2 \geq W_1$ $\delta_W = 1.0$
$W_2 < W_1$ $\delta_W = 0$
δ_W
$\delta_A \delta_W$ = Cargo-Carrying Parameter, CC
$A_2 \geq A_1$ $\delta_A = 1.0$
$A_2 < A_1$ $\delta_A = 0$
A_2
A_1
δ_A
60 Fraction
% HP Utilized
% Design or Base Speed
%Hp Utilized
1/100
Fraction
100
(Assume Craft Has Two Engines Operating)
SFC Correction Factor
% HP Installed
V(VIS)/V_B
Installed HP
1/2
Vcalm
HP/Ton
Reduced or On-Scene Position
(Rate 3,4)
(Rate 1,2)
Flank or Cruise Speed Position
SFC
Gas Turbine
Hp/2
Lbs/Hp-Hr
Corrected
SFC
Diesel
Hp/2
Lbs/HP-HR
HP/TON-KNOT
Speed (RATE)
Craft Type Select
Speed-Engine Type Table
Gas Turbine or Diesel Engine Select


9
Survivability
Go Fraction
Go Fraction
1/100
Fraction Hp Utilized
Hp Utilized
Calm-Water (or Low-Visibility) Rate
Gal/Hr Utilized
Invert
hr/Gal
Gal. Fuel
Endu
Gal/Hp-Hr
335/2240 Gal/Lb
Vcalm
Corrected Lbs/Hp-Hr
Gas Turbine
Lbs Fuel/HP-Hr
Diesel
Weighted Average Fuel Rate
Weighted Average Velocity
Parameter
Master Task
ASST
BORD
MNPC
RTRV
WAIT
WEQD
WEQP
SDIU
SESC
SPAT
SPEO
TOWS
ESCT
IDNT
PATL
STGT
TRPT
Speed Select
Master Task
Parameter MN
Rate (Speed)
MN

10

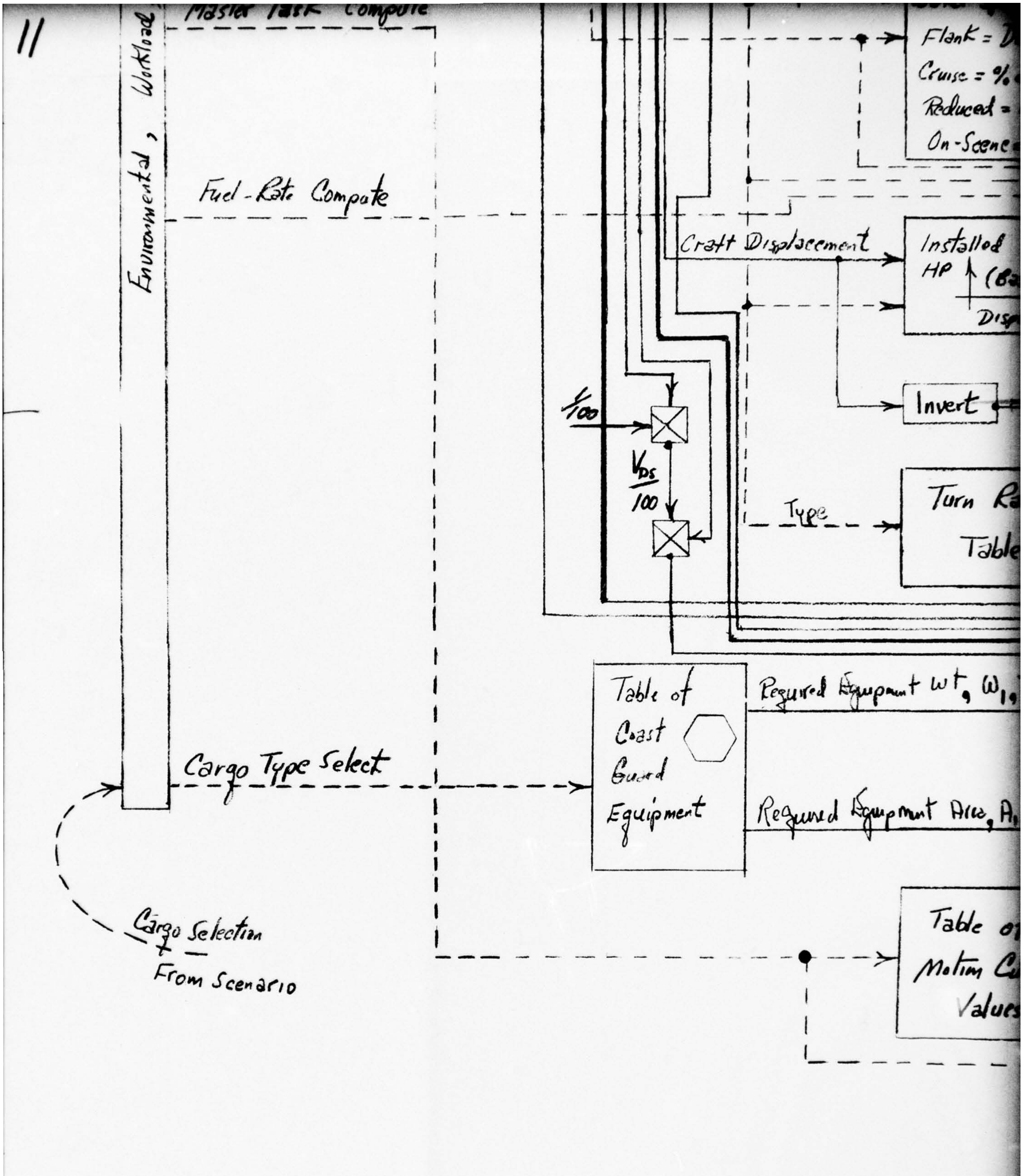


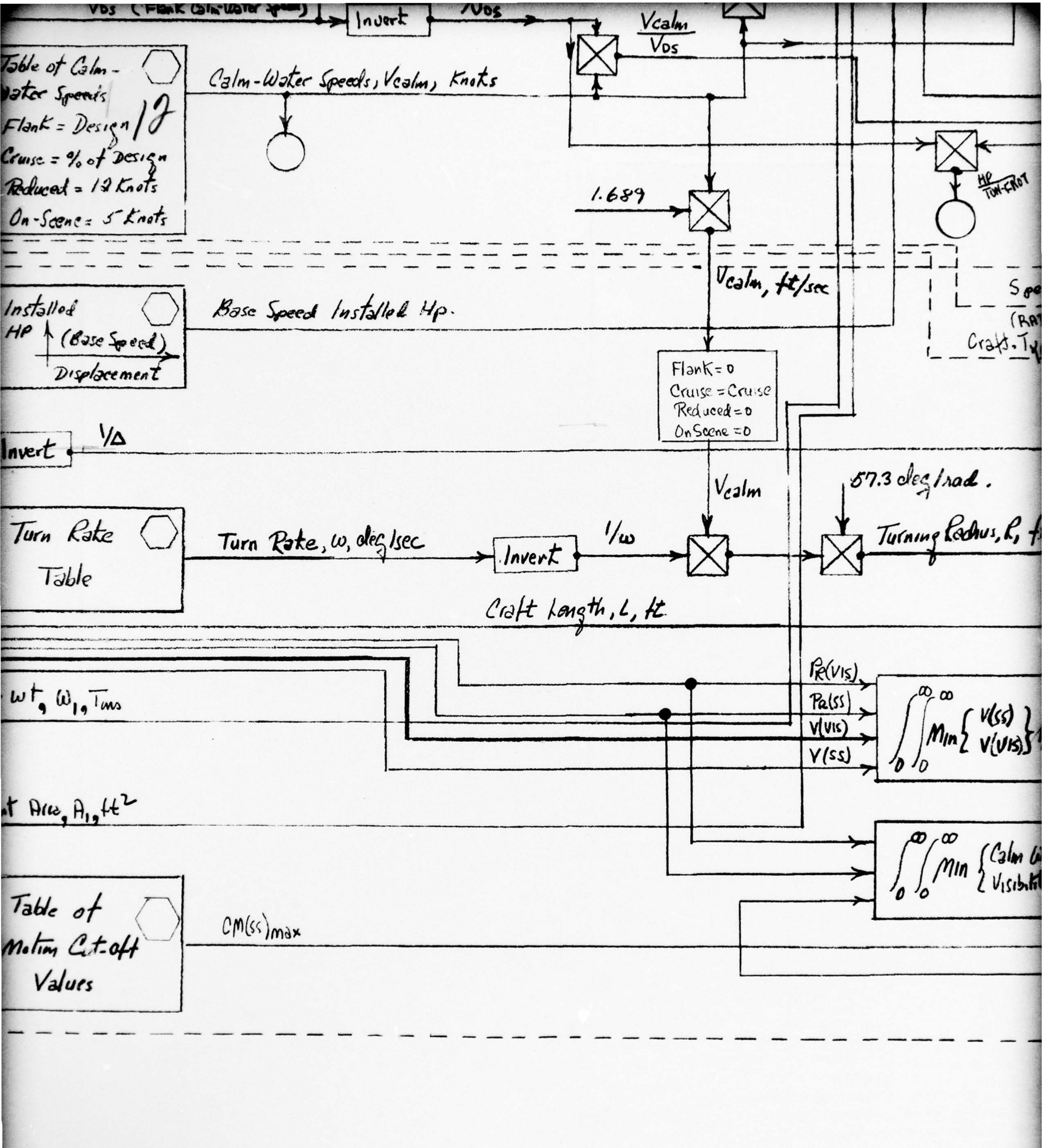
Master Task \ Parameter	MN	DF	CC*	LS	TW
ASST	MN	DF	1.0	LS	1.0
BORD	MN	DF	1.0	LS	1.0
MNPC	MN	DF	1.0	LS	1.0
RTRV	MN	DF	1.0	LS	1.0
WAIT	1.0	1.0	1.0	LS	1.0
WEQD	1.0	DF	1.0	LS	1.0
WEQP	MN	DF	1.0	LS	1.0
SDIU	1.0	DF	1.0	LS	1.0
SESC	1.0	1.0	1.0	LS	1.0
SPAT	1.0	DF	1.0	LS	1.0
SPEO	1.0	DF	1.0	LS	1.0
TOWS	MN	1.0	1.0	LS	TW
ESCT	1.0	1.0	1.0	LS	1.0
IDNT	MN	1.0	1.0	LS	1.0
PATL	1.0	1.0	1.0	LS	1.0
STGT	1.0	DF	1.0	LS	1.0
TRPT	1.0	1.0	CC	LS	1.0
TRST	1.0	1.0	1.0	LS	1.0

Weighted Average Velocity*

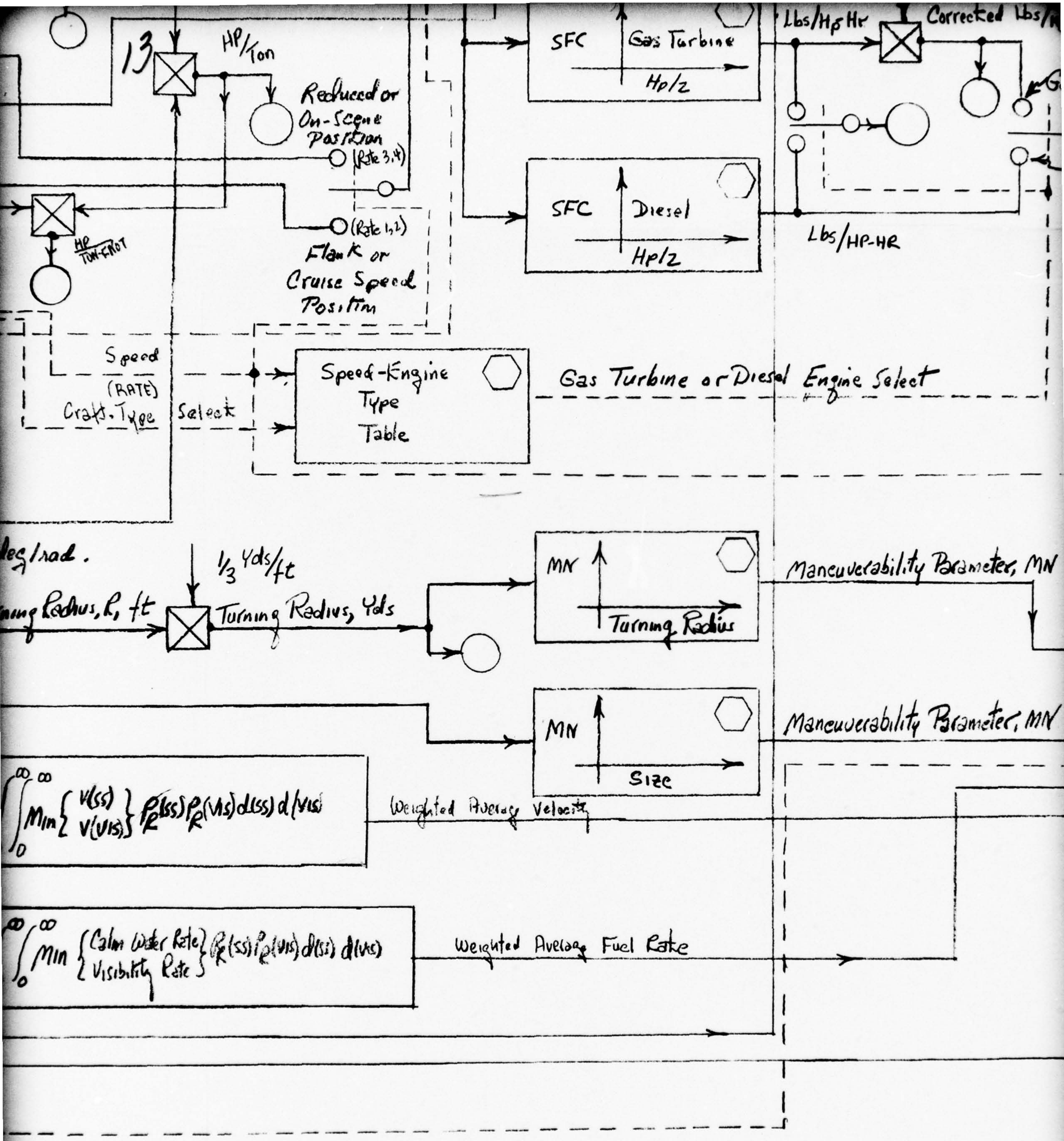
Inputs to Scenario

11

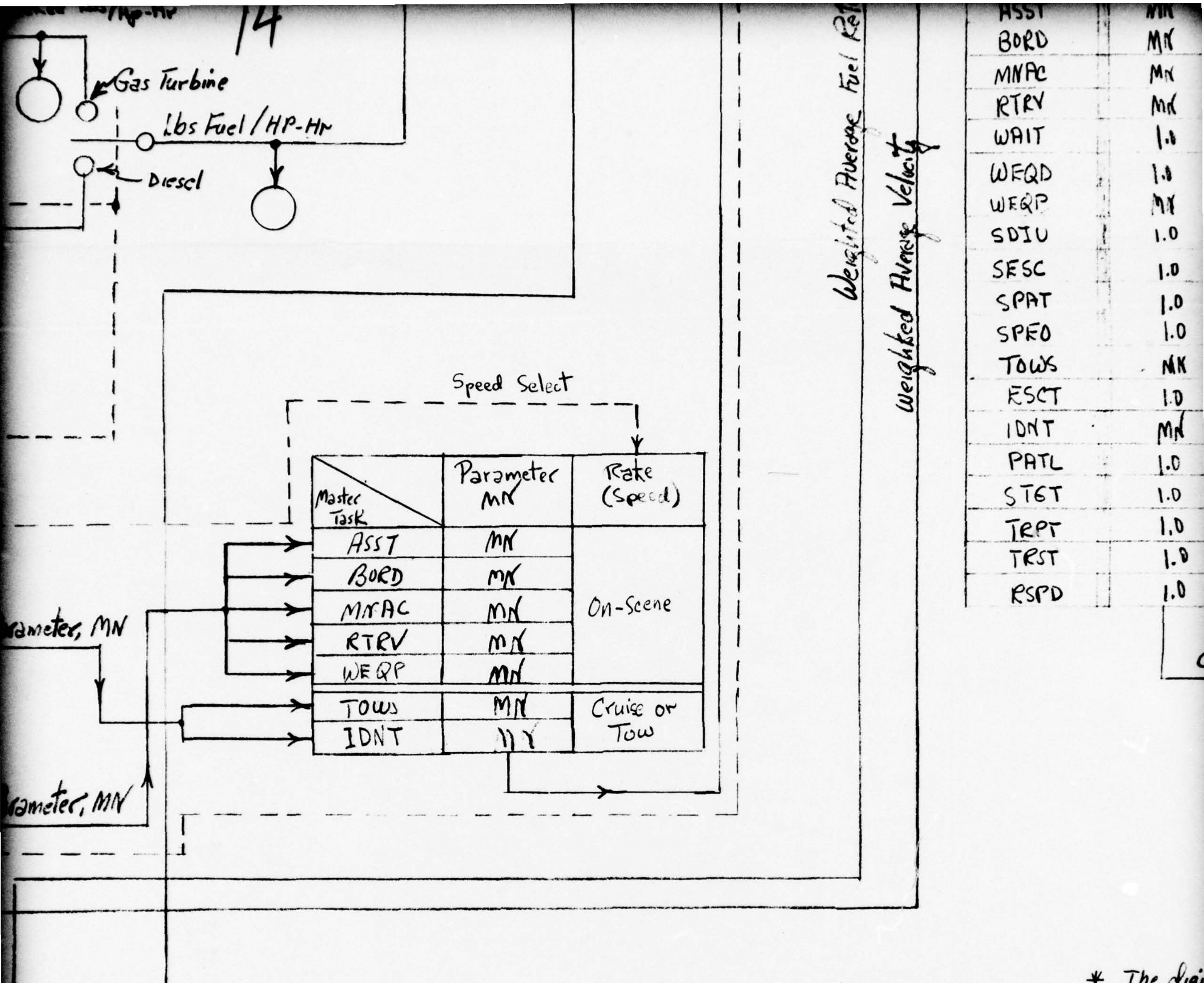

Master Task Compute
Environmental, Workload
Flank =
Cruise = %
Reduced =
On-Scene
Fuel-Rate Compute
Craft Displacement
Installed HP
Invert
1/100
V_{DS}/100
Type
Turn
Table
Table of Coast Guard Equipment
Required Equipment wt, W_1,
Cargo Type Select
Required Equipment Area, A_1
Table of Motion
Values
Cargo Selection From Scenario



VDS (Flank Calm-Water Speed)
Invert
1/VDS
Vcalm / VDS
Table of Calm-Water Speeds
Flank = Design
Cruise = % of Design
Reduced = 12 Knots
On-Scene = 5 Knots
Calm-Water Speeds, Vcalm, Knots
1.689
HP / TON-KNOT
Vcalm, ft/sec
Installed HP (Base Speed) Displacement
Base Speed Installed Hp.
Flank = 0
Cruise = Cruise
Reduced = 0
OnScene = 0
Invert
1/Δ
Vcalm
57.3 deg/rad.
Turn Rate Table
Turn Rate, ω, deg/sec
Invert
1/ω
Turning Radius, R,
Craft Length, L, ft.
PR(VIS)
PR(SS)
V(VIS)
V(SS)
Min V(SS) V(VIS)
Min Calm Visibility
Table of Motion Cut-off Values
CM(SS)max



13
HP/Ton
Reduced or On-Scene Position
(Rate 3,4)
(Rate 1,2)
Flank or Cruise Speed Position
HP/TON-KNOT
SFC
Gas Turbine
Hp/z
SFC
Diesel
Hp/z
Lbs/Hp Hr
Corrected Lbs/
Lbs/HP-HR
Speed
(RATE)
Craft Type
Select
Speed-Engine Type Table
Gas Turbine or Diesel Engine Select
deg/rad.
1/3 Yds/ft
Turning Radius, R, ft
Turning Radius, Yds
MN
Turning Radius
Maneuverability Parameter, MN
MN
Size
Maneuverability Parameter, MN
$\int_0^{\infty}\int_0^{\infty} Min \left\{ \begin{matrix} V(SS) \\ V(VIS) \end{matrix} \right\} P_R(SS) P_R(VIS)\, d(SS)\, d(VIS)$
Weighted Average Velocity
$\int_0^{\infty}\int_0^{\infty} Min \left\{ \begin{matrix} \text{Calm Water Rate} \\ \text{Visibility Rate} \end{matrix} \right\} P_R(SS) P_R(VIS)\, d(SS)\, d(VIS)$
Weighted Average Fuel Rate



Master Task	Parameter MN	Rate (Speed)
ASST	MN	On-Scene
BORD	MN	
MNAC	MN	
RTRV	MN	
WEQP	MN	
TOWS	MN	Cruise or Tow
IDNT	MN	

ASST	MN
BORD	MN
MNAC	MN
RTRV	MN
WAIT	1.0
WEQD	1.0
WEQP	MN
SDIU	1.0
SESC	1.0
SPAT	1.0
SPED	1.0
TOWS	MN
ESCT	1.0
IDNT	MN
PATL	1.0
STET	1.0
TRPT	1.0
TRST	1.0
RSPD	1.0

SYMBOL	SPECIFICATION	CODE IDENT	PART OR IDENT NO.	FIND NO

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DO NOT SCALE THIS DRAWING

MATERIAL

FINISH

DRAWN

CHECKED

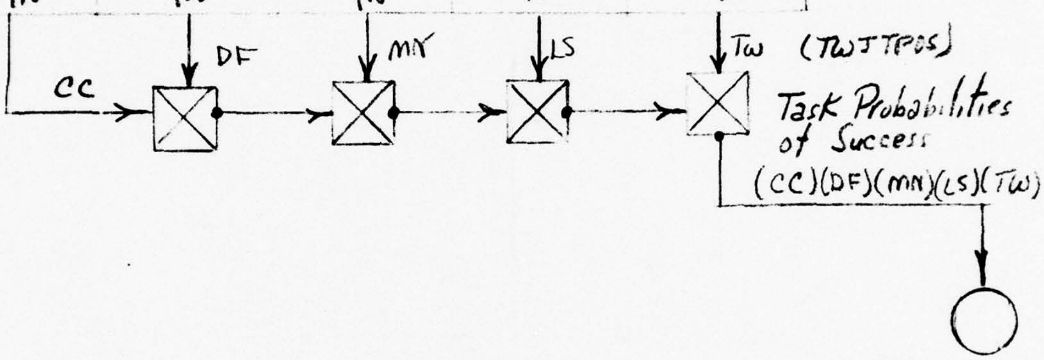
APPROVED

APPROVED

NEXT ASSY	USED ON
APPLICATION	

Weighted Average Velocity

RTRV	MN	DF	1.0	LS	1.0
WAIT	1.0	1.0	1.0	LS	1.0
WEQD	1.0	DF	1.0	LS	1.0
WEQP	MN	DF	1.0	LS	1.0
SDIU	1.0	DF	1.0	LS	1.0
SESC	1.0	1.0	1.0	LS	1.0
SPAT	1.0	DF	1.0	LS	1.0
SPEO	1.0	DF	1.0	LS	1.0
TOWS	MN	1.0	1.0	LS	TW
ESCT	1.0	1.0	1.0	LS	1.0
IDNT	MN	1.0	1.0	LS	1.0
PATL	1.0	1.0	1.0	LS	1.0
STGT	1.0	DF	1.0	LS	1.0
TRPT	1.0	1.0	CC	LS	1.0
TRST	1.0	1.0	1.0	LS	1.0
RSPD	1.0	1.0	1.0	LS	1.0



* The digit 1 is not an indication of POS (Scenario Dependent)

CODE IDENT	PART OR IDENT NO.	FIND NO	QTY REQD	MATERIAL	NOMENCLATURE

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DRAWING

DRAWN

CHECKED

APPROVED

APPROVED

DEPARTMENT OF TRANSPORTATION

TRANSPORTATION SYSTEMS CENTER

55 BROADWAY CAMBRIDGE, MASSACHUSETTS 02142

Cutter Resource Effectiveness Evaluation Model
Appendix B to Vol II - Evaluation of Craft Performance in Coast Guard Programs
Schematic of Craft/Task Evaluation Computer Program

SIZE	CODE IDENT NO.	DRAWING NO.
F		

SCALE | SHEET

APPENDIX C

MASTER TASK* TIME COMPUTATIONS

This appendix explains the rationale and the computational methods used to determine the time to perform a task. The time to perform a task varies with the environment, the craft and the workload. All of these factors are considered in the computations that follow.

There are two general classifications of tasks, one type being when the craft is on scene in a given location, and the other being when the craft is traveling from point to point. The on-scene task times are generally a function of the magnitude of the job, the craft maneuvering characteristics, and the craft's motion characteristics due to the environment. The traveling task times on the other hand are primarily a function of the distance and craft speed in the particular seaway. The following paragraphs detail the specific computations for all master tasks.

1. Assist - The user assigns a time, T_u, to perform the activity (passing a gasoline can, pump, etc.) in calm water. Craft motion causes an increase in the time to perform this task according to the following relationship:

$$T = T_u * f(SK)$$

where: T is the calculated time to perform the task

T_u is the user inputted base time

f(SK) is a time multiplier function accounting for craft motion.

f(SK) is defined by the curve in Figure C-1 as seen below:

2. Board - The user assigns a time, T_u, to board under ideal conditions (calm water and excellent maneuverability). An increase in craft motion or poor craft maneuverability both cause an increase in the time necessary to board according to the following relationship:

$$T = T_u * f(SK) * g(MN)$$

where: T is the calculated time to perform the task

T_u is the user inputted base time

*Each Master Task models one or more slave tasks as shown in Table 3-1.

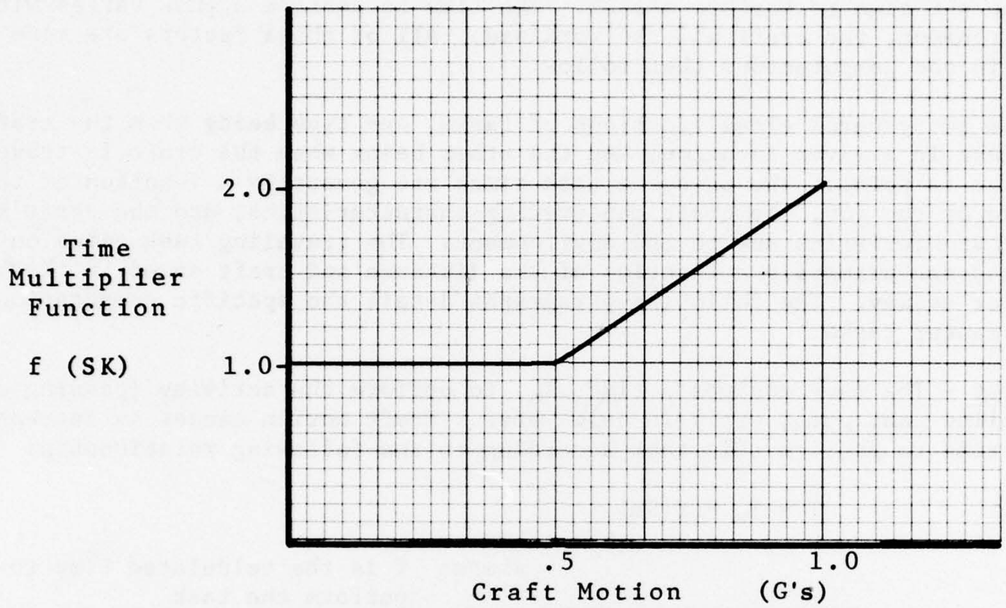


Figure C-1 DEFINITION OF TIME MULTIPLIER FUNCTION f(MO)

and continued from the proceeding

f(SK) is a time multiplier function accounting for craft motion (Figure C-1)

g(MN) is a time multiplier function accounting for craft maneuverability; as defined by the curve in Figure C-2.

3. <u>Monitor Activities</u> - The time, T_u, that the user supplies for this task represents the duration of the event to be monitored. The characteristics of the CG craft have no effect upon this event (e.g., an offshore platform leaking oil). Thus,

$$T = T_u$$

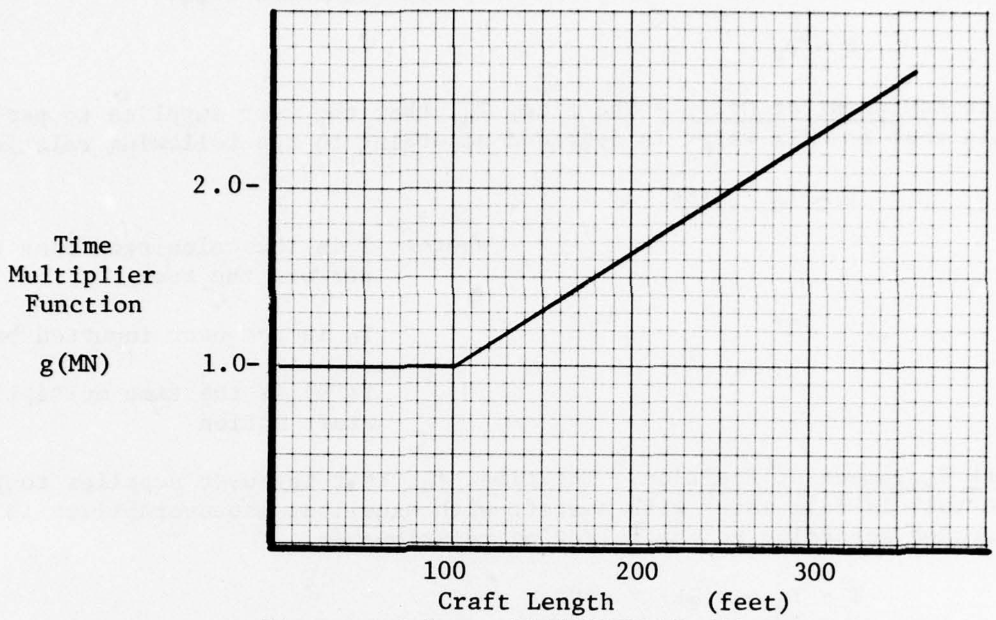


Figure C-2 DEFINITION OF TIME MULTIPLIER FUNCTION g(MN)

4. <u>Retrieve</u> - The user-supplied time, T_u, is the time necessary to retrieve in calm water using a craft with excellent maneuverability. The time is increased with craft motion and lesser maneuverability according to the following relationship:

$$T = T_u * F(SK) * G(MN)$$

where: T is the calculated time to perform the task

T_u is the user inputted base time

f(SK) is the time multiplier function to account for craft motion (Figure C-1)

g(MN) is the time multiplier function to account for craft manueverability (Figure C-2).

5. <u>Wait</u> - The user-supplied time, T_u, represents the time that the Coast Guard craft must wait while an event takes place somewhere else.

$$T = T_u$$

6. <u>Work Equipment at Drift</u> - The time, T_u, that the user supplies to perform this task in calm water is degraded according to the following relationship:

$$T = T_u * f(SK)$$

where: T is the calculated time to perform the task

T_u is the user inputted base time

f(SK) is the time multiplier for craft motion

7. <u>Work Equipment at Position</u> - The time, T_u, that the user supplies to perform the task in calm water with a craft with excellent maneuverability is degraded according to the following relationship:

$$T = T_u * f(SK) * g(MN)$$

where: T is the calculated time to perform the task

T_u is the user inputted base time

f(SK) is the time multiplier function to account for craft motion (Figure C-1)

g(MN) is the time multiplier function to account for craft maneuverability (Figure C-2).

8. <u>Search Distressed Unit</u> - See Appendix D.

9. <u>Search for People</u> - See Appendix D.

10. <u>Slow Escort</u> - The user supplies both the distance, D_u, to escort and the escort speed, V_u, and the time is simply distance divided by speed as follows:

$$T = D_u/V_u$$

11. <u>Slow Patrol</u> - The user supplies both the distance to patrol, D_u, and the patrol speed, V_u. (If the patrol intent is to cover an area, the user must first convert this area to a distance using a nominal track spacing.) Then, time is the distance divided by the speed as follows:

$$T = D_u/V_u$$

12. Towing - The user supplies the distance D_u, to tow. The tow speed, V_{tow}, is computed in the program as discussed in Section 3.1.2, Tow Parameter. The time required to tow is the distance divided by the tow speed, or

$$T = D_u/V_{tow}$$

13. Escort - The user distance, D_u, to escort is used in conjunction with the craft cruise average speed, $\overline{V}_c$, in a seaway. The average cruise speed, $\overline{V}_c$, is dependent upon the craft's speed-sea state envelope and the user inputted expected sea state distribution (detailed in Craft/Task Evaluation Schematic Appendix B). The time to escort is then:

$$T = D_u/\overline{V}_c$$

14. Identify - The user supplies the inputs of distance, D_u, between vessels, the number, N_u, of vessels to identify and the time to Identify one vessel. The average cruise speed, $\overline{V}_c$, and the user inputted expected visibility are used in conjunction with the foregoing inputs to determine the time to Identify vessels. The average cruise speed, $\overline{V}_c$, is detailed in Appendix B. The expected visibility is converted to a multiplicative time function, h(VZ) where:

$$h(VZ) = \sum_{i=1}^{3} P(Z)_i * f(Z_i)$$

where: P(Z) is the probability of visibility with:
$P(Z)_1$ = Good
$P(Z)_2$ = Fair
$P(Z)_3$ = Poor

and, f(Z) is a weighting factor for poor visibility with:
$f(Z_1) = 1.0$
$f(Z_2) = 1.0$
$f(Z_3) = 2.0$

The time to Identify is determined using the following relationship:

$$T = N_u * (T_u * h(VZ) + D_u/\overline{V}_c) - D_u/V_c$$

where: T is the calculated time to perform the task

N_u is the number of vessels to be identified

T_u is the user inputted base time to identify

$h(VZ)$ is the visibility multiplicative factor

D_u is the distance between vessels to be identified

$\overline{V}_c$ is the average cruise speed

15. Patrol - The user supplied distance to patrol, D_u, is used with the average cruise speed, $\overline{V}_c$, and the time determined by the following relationship:

$$T = D_u/\overline{V}_c$$

16. Search Target - See Appendix D.

17. Transit - The user-supplied distance, D_u, to transit is utilized with the average cruise speed, V_c, and the time determined by the following relationship:

$$T = D_u/\overline{V}_c$$

18. Transport - The user-supplied distance, D_u, to transport equipment is used with the cruise average speed, $\overline{V}$, and the time determined by the following relationship:

$$T = D_u/\overline{V}_c$$

19. Respond - *The user input distance*, D_u, *to respond* is used with the average flank speed, $\overline{V}_f$, and the time determined by the following relationship:

$$T = D_u/\overline{V}_f$$

APPENDIX D

SEARCH TASK EQUATION DEVELOPMENT

The search tasks or groups are different from the other tasks of the CREE model in that they have three ports, one input and two outputs. The two outputs represent possible success and failure paths. The frequencies, or probabilities, of success or failure of any search depend upon the specific values of the operational variables and hence are not known beforehand when constructing the scenario. These frequencies are, therefore, computed for each of the search tasks: Search Target, Search People, and Search Distressed Unit. In addition, the times associated with successful and unsuccessful searches are computed.

There are two types of three-port search tasks considered in the model, SAR searches and Target searches. The variables affecting a SAR search are visual sweep width, coverage factor, area of initial search, maximum number of searches, maximum search time, and the speed of the searching craft. The variables affecting a Target Search are the target ship's speed and uncertainty of location, plus the radar sweep width, the maximum allowable time for the search and the speed of the searching vessel. The computational procedure to determine the frequency of success and failure and the associated search times are developed in the following paragraphs.

1. SAR Searches - These two search tasks, Search for People, and Search for Distressed Unit, incorporate the standard Coast Guard doctrine described in CG-308 SAR Manual. It is assumed that the search pattern which best fits the situation, such as creeping line or expanding square, will be chosen by the operator on the scene and, therefore, not applicable in this model. The curves in the SAR Manual relate the probability of detection to the coverage factor and the number of searches. The procedures used in the CREE Model for SAR Searches are just those necessary to adapt the physical description of the operation to this established Coast Guard doctrine.

   The determination of the probability of detection (POD) from the SAR search curves is simply a matter of reading the POD for a particular number of searches of the area for a given coverage factor. The POD curves are shown in Figure D-1. Subsequent searches expand the search area according to the schedule shown in Table D-1.

TABLE D-1

SCHEDULE OF EXPANDING SEARCH AREAS

SEARCH NUMBER	n	1	2	3	4	5
Multiple of the Initial Search Area	$\alpha(n)$	1.00	2.11	3.31	4.37	5.16

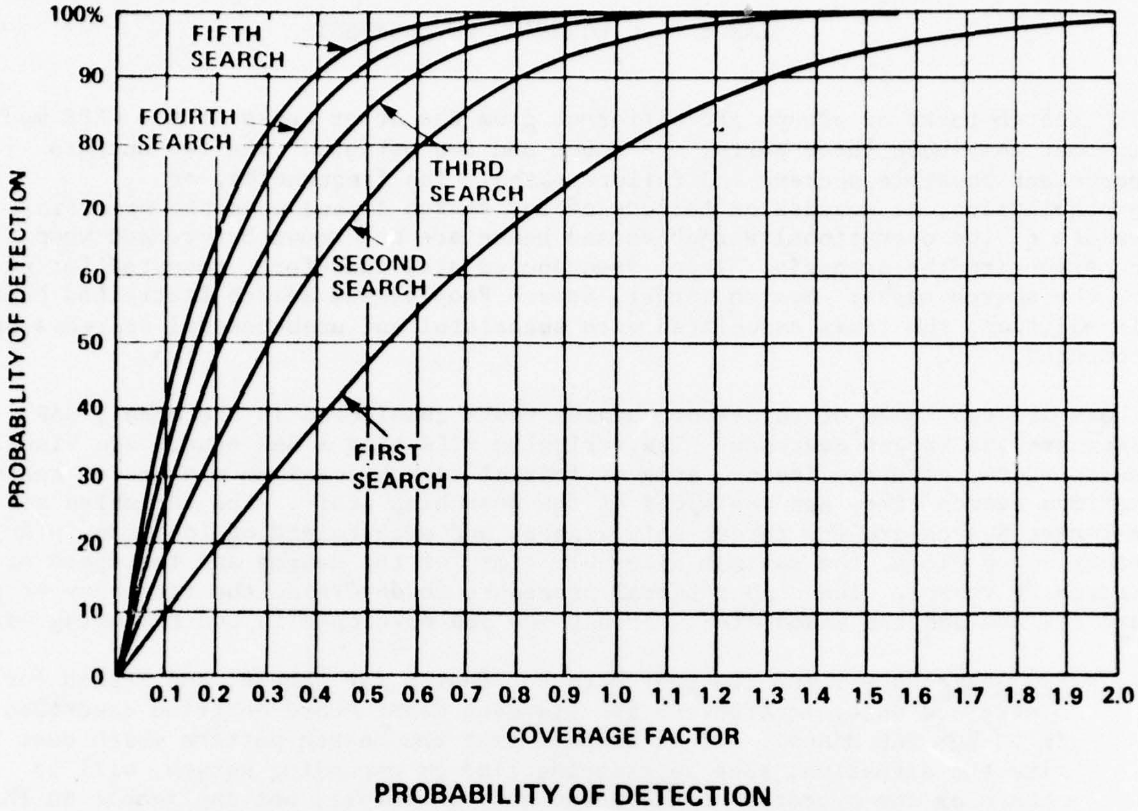


Figure D-1. POD DETECTION VERSUS COVERAGE FACTOR CURVES ((CG-308) SAR MANUAL)

Each search takes longer than the previous one since a greater area must be swept with the same coverage factor. The time, T_n, to perform the nth search is:

$$T_n = \frac{CF*A(n)}{SW*V}$$

where: CF ≡ Coverage Factor
A(n) ≡ Area of nth search
V ≡ Average speed of search craft
SW ≡ Visual sweep width

The term $\frac{CF*A(n)}{SW}$ is equivalent to the distance that the search craft must travel on the n^{th} search. It is desirable to rewrite the search area A(n) in terms of the initial search area A(1). The resulting expression is then in terms of all of the initial descriptions of the search problem and the multiplying factor as specified by SAR doctrine.

$$T_n = \frac{CF \cdot A(1) \cdot \alpha_n}{SW \cdot V}$$

The actual time spent on a SAR search is dependent upon its outcome. If the distressed unit is not found, the time to perform the search is simply the sum of the times to perform each individual sweep, i.e.,

$$\bar{T}_{not\ find} = \sum_{n=1}^{N_{max}} T_n = \frac{CF \cdot A(1)}{SW \cdot V} \sum_{n=1}^{N_{max}} \alpha(n)$$

The time spent in a successful search is the expectation value of T, as follows:

$$\bar{T}_{find} = \frac{\sum_{n=1}^{N_{max}} [P_r(n,c) - P_r(n-1,c)][(\sum_{i=1}^{n} T_i) - \frac{T_n}{2}]}{\sum_{n=1}^{N_{max}} [P_r(n,c) - P_r(n-1,c)]}$$

where: $P_r(n,c)$ is the cumulative probability of finding the craft on the n^{th} search with a coverage factor of c. This value is read from the POD curves of Figure D-1.

This procedure assumes that it is equally probable to find a craft in any increment of a given search, and implies that if the distressed unit is found on the n^{th} search, on the average it is found in half of the time necessary to complete the whole search. This is the origin of $T_n/2$ term in the above expression.

2. Target Searches - A Target Search is a search for a vessel that is attempting to steam away from a given point. The subject vessel does not want to be detected, unlike the distressed unit which wants to be found. The incident is assumed to be reported to the Coast Guard in the CREE Model scenario, and the CG vessel transits or interdicts to the scene. The ensuing search proceeds until the vessel is detected or the search is terminated by the maximum time limit inputted by the user.

The conditions of the search are described by the following variables:

SW: the searching vessel's radar sweep width

V: the speed of the searching vessel

t: time

e: the initial uncertainty in target position

V_t: the target vessel's speed

T_b: the time it takes for the searching vessel to arrive at the initial position to start the search

T_{max}: The user inputted maximum time for the search

At the instant that the Coast Guard receives the call to investigate, the subject vessel may be anywhere in an area

$$\pi \epsilon^2$$

When the Coast Guard vessel arrives on the scene, the subject vessel may be anywhere in the newly expanded area,

$$\pi (\epsilon + V_t T_b)^2$$

At this point the time for the Search for target task begins. At any later time, t, the target vessel, may be anywhere in the area

$$\pi [\epsilon + V_t (T_b + t)]^2$$

In the CREE Model the search is limited by a user imposed time, T_{max}.

The quantities that describe the results of the search are the probability of detection, which results in the frequency, or probability, of finding and not finding, and the length of time associated with finding and not finding.

The probability of finding a target during the interval, Δt, at any time t is defined as:

$$P_{find}(\Delta t, t) \equiv \frac{\text{Area searched during interval } \Delta t}{\text{Area remaining to be searched}}$$

which can be expressed as:

$$P_{find}(\Delta t, t) = \frac{sw * v * \Delta t}{\pi[\varepsilon + V_t(T_b + t)]^2 - sw * v * t}$$

The probability of not finding is the probability of finding subtracted from one, or:

$$P_{not\ find} = 1 - P_{find}$$

The probability of not finding the target in the interval Δt as Δt ranges from zero to T_{max} is simply the product of not finding during each interval Δt, or:

$$P_{not\ finding} \Big|_{t=0}^{t=T_{max}} = \prod_{t=0}^{t=T_{max}} P_{not\ find}(\Delta t, t)$$

The probability of finding the target in the interval from t=0 to $t=T_{max}$ is then:

$$P_{find} \Big|_{t=0}^{t=T_{max}} = 1 - \prod_{t=0}^{t=T_{max}} [1 - P_{find}(\Delta t, t)]$$

The times associated with finding and not finding the target are:

$$T_{not\ find} = T_{max}$$

$$T_{find} = E(t) = \frac{\sum_{t=0}^{t=T_{max}} (t - \frac{\Delta t}{2}) P_{find}(\Delta t, t)}{\sum_{t=0}^{t=T_{max}} P_{find}(\Delta t, t)}$$

Two cases of target searches are possible, one for a fast searching vessel which theoretically could always find the target depending on the value of T_{max}, and the other for a slow vessel which may or may not find the target. These two cases are illustrated in Figure D-2.

In the case of the fast, or high speed search, the target vessel is found when the areas for the searching craft and target craft are equal. This will occur, as seen in Figure D-2, at time T_1. In the CREE Model this search would be terminated with 100 percent success at time T_1, provided T_{max} is greater than T_1; if not, the search is terminated at T_{max} with a probability of success equal to the ratio of the searched area to the area of the target.

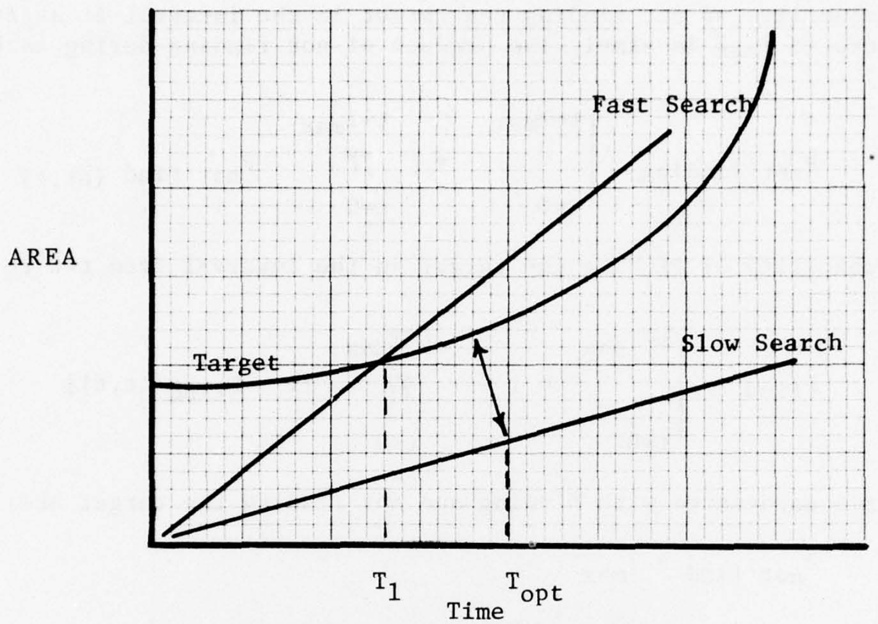


Figure D-2 AREA-TIME CURVE FOR TARGET SEARCHES

In the case of the slow speed search where the area searched never equals the target area, the search is terminated at T_{max} with the appropriate probability of success. Clearly there is some optimum time for this slow speed search, i.e., when the ratio of the searched area to the target area is a maximum. This is indicated by T_{opt} in Figure D-2 and can be expressed as:

$$T_{opt} = \frac{1}{V_t} \left[\frac{SW * V}{2\pi} - (\varepsilon + V_t T_b)\right]$$

For this slow speed case, the CREE Model terminates the search at the user inputted T_{max}.

APPENDIX E

GLOSSARY AND LIST OF ABBREVIATIONS USED IN CREE MODEL REPORT

ACV - Air Cushion Vehicle

ANB - Aid to Navigation Boat

AVERAGE SORTIE - A sortie, consisting of parts of every task occurring in the scenario, obtained by weighing each sortie in the scenario by its probability of success and frequency of occurrence.

CALCOMP - California Computer (Graph Plotting Program)

CG - Coast Guard

CHAR - Craft Characteristics Computer Program

CREE MODEL - Cutter Resource Effectiveness Evaluation Model

DE - Diesel Engine

DECISION POINT PROBABILITIES - The probabilities chosen by the user at a branch point in the scenario

ELT - Enforcement of Laws and Treaties

FLOW CHART SCENARIO - A model of Coast Guard Program (scenario) in a flow chart format (like a wiring diagram)

FORCE MIX - The CREE Model does not address force mix analysis

FREQUENCY OF OCCURRENCE - The probability of occurrence (frequency is used to imply how often)

FUEL FRACTION - The fraction of useful load that is carried as fuel on board

FUNCTIONAL TASK GROUP - A group of tasks in a mini-flow chart (or module) that together model a particular activity (or function)

F_F - Fuel Fraction

G-OP - Operations Planning & Staff in Coast Guard Headquarters

GT - Gas Turbine

HPWC - High Performance Water Craft

IOCS - Input Output Computer Services (Incorporated)

LNG - Liquefied Natural Gas

MASTER TASK - A single task which models a class of similar actions by the Coast Guard vessel

MEP - Marine Environmental Protection

MLB - Motor Life Boat

MRB - Motor Rescue Boat

MSA - Marine Science Activities

OPERATIONAL ACTIVITIES - Missions or functions performed by CG personnel and units. The broad partitioning of activities when analyzing CG programs.

OPERATIONAL REQUIREMENTS - Those items that are necessary to fully describe the operational choices, environment and area of operation. Examples are decision point probabilities, sea state and distances to steam.

PARAM - Parameter section of the CREE Model Computer Program

PARAMETER - A multiplying factor (indicative of an effect such as sea state upon a task) which degrades the probability of success of that task.

PERCENT OF SCENARIO COMPLETED - The percent of all of the sorties in the scenario that the craft may complete without either running out of fuel or exceeding the time limit (sortie duration) for a sortie.

POD - Probability of Detection

PROBABILITY OF SUCCESS - The ratio of the number of times an event is performed successfully to the number of times it is attempted.

PROBABILITY OF SUCCESSFULLY COMPLETING SCENARIO - The average probability of success of every sortie in the scenario. (A way to visualize this "average probability of success" is to consider the case where every sortie has an individual probability of success of either 1.0 or 0.0. The fraction of the sorties in the scenario with 1.0 would represent the probability of successfully completing the scenario.)

PROBABILITY OF SUCCESSFUL OCCURRENCE (OF A SORTIE) - The product of the sortie frequency of occurrence and the sortie probability of success.

PROPOS - Program (CG) Probability of Success element of the CREE Model Computer Program.

PSS - Port Safety & Security

PWB - Port & Waterways Boat

P/L - Pressure to length ratio; used in describing Air Cushion Vehicles

RANGE FRACTION - The fraction of the craft's fuel capacity (which equates to range) that may be expended in an operation. The remainder is the fuel reserve which may not be expended in the scenario.

R&DC - Research and Development Center

SAR - Search and Rescue

SEA STATE DISTRIBUTION - The probability distribution of sea states in a given region over the extended time of operation.

SCENARIO - A sequencing or flow of events of an operation

SES - Surface Effect Ship

SORTIE - A sequence of tasks performed by a craft with a logical beginning and end; for example, a SAR case starting from the pier, continuing through the operation, and finally terminating at the pier.

SORTIE DURATION - The maximum allowable time for any sortie in a given scenario.

SS - Sea State

SWATH - Small Waterplane Area Twin Hull

SYSTEM - Not mentioned in the CREE Model reports

TASK - The lowest level of discrete activity such as a transit or tow in a Coast Guard Program.

TOWING DISTRIBUTION - The distribution of craft, according to length or displacement, to be towed in the region of operation.

TPOS - Task Probability of Success section of the CREE Model Computer Program.

TSC - Transportation Systems Center

UTB - Utility Boat

VISIBILITY DISTRIBUTION - The distribution of visibility in the region of operation.

WHEC - High Endurance Cutter

WMEC - Medium Endurance Cutter

WPB - Patrol Boat

Δ - Displacement

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